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**Review and Analysis of Data**  
**On**  
**Tire Failure Rate During High-speed Testing**

**Date: Monday, April 22, 2002**

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## **EXECUTIVE SUMMARY**

The Transportation Recall Enhancement, Accountability, and Documentation (T.R.E.A.D.) Act of **2000** mandates a rulemaking proceeding to revise and update our safety performance requirements for tires. In response to this mandate, NHTSA initiated a tire-testing program including a series of high-speed tests<sup>1</sup>. The goal of these tests is to establish the maximum speed at which a tire can function without failure.

The Rubber Manufacturers Association (RMA) also provided test results of high-speed tests of tires with Speed Rating of S, T, and H (included in Docket 8011, Entry#: 7). These tests were conducted at **180,240, and 300** kPa inflation pressures. The tires were subjected to a load equal to 80 or 90 percent of the tire's maximum load carrying capacity, as marked on the sidewall. During these tests, the speed was incrementally increased until each tire failed.

NHTSA's Research & Development (NRD) conducted high-speed tests of P-metric tires also with Speed Ratings of S, T, and H. These tests were conducted at somewhat different inflation pressures of **140,210, and 220** kPa. The tires were subjected to a load equal to 70, 80, and 85 percent of the tire's maximum load carrying capacity, as marked on the sidewall. Again, in parallel with the RMA testing, the speed was incrementally increased until each tire failed.

As outlined above both the RMA and NHTSA conducted high-speed tests by varying the following factors: 1) Pressure, 2) Load, 3) Step Duration, and 4) Speed Rating i.e. S, T, & H.

Test results from the RMA and NHTSA are in the form of time-to-failure and speed-at-failure. This analysis attempts to address the relationship of the factors above with speed-at-failure of the tire.

The significance of The Tire and Rim Association's (T&RA) "load formula" and the curve generated by using the formula (load curve) is also studied. An understanding of the relationship between the tests conducted and the tire load or performance curve will help in determining specifications of test conditions for future tests.

Additional high speed testing has been done by NHTSA and the results are included in Docket **8011**, entry##**22**). The results of these tests are not included in the analysis in this report because it was preliminary and only tested one sample of each type of tire.

### **Conclusions:**

There is a definite but small decrease in the average speed-at-failure for tires tested at 90 percent of maximum sidewall load compared to tires tested at 80 percent of maximum sidewall load.

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<sup>1</sup> Docket NHTSA-2000-8011, at [hppt://dms.dot.gov](http://dms.dot.gov)

Inflation pressure has a significant effect on speed-at-failure. Inflation pressure of 26 psi produces a substantial number of failures at speeds less than the speed rating of the tire. Inflation pressure of 35 psi produces only a small number of failures below the speed rating of the tire.

The combination of NHTSA and RMA data support the hypothesis that the performance of a tire is the same for a test condition anywhere on the T&RA load curve (with an inflation pressure of 26 psi or more.) At lower pressures, specifically at 20 psi, failure rates are higher than would be predicted from the T&RA curve.

For high-speed tests at the maximum sidewall pressure, (35 psi for the tires tested) it is necessary to test with durations greater than 10 minutes to fully judge failure rates.

How would the tires tested in these programs perform in the proposed high-speed test and the high-speed, low-pressure test (“Alternative 2”)?

The proposed high-speed test is run at 32 psi and **85** percent of sidewall load. The high-speed, low-pressure test (“Alternative 2”) is run at 20 psi and 67 percent of sidewall load. The duration at each speed would be **30** minutes. It can be seen from Figure 3 1 that both of these points are slightly below the T&RA curve. The test would start at a speed of **140km/h** and would increase in 10km/h increments until it reaches a speed of 160km/h or the tire fails. The tire is considered to have passed if it completes 30 minutes at 160km/h. An estimate of the number that would pass, based on the tests discussed in the study, is given below:

32 psi test (based on RMA data)

S-rated tires: 100percent would have passed.  
T-rated tires: 100percent would have passed.  
H-rated tires: 100percent would have passed.

20 psi test (based on NHTSA data)

S-rated tires: 70.0 percent would have passed.  
T-rated tires: 100percent would have passed.  
H-rated tires: 100percent would have passed.

An extrapolation of these results for tires with speed ratings of Q, and R tires is shown in Appendix 6.3. That analysis suggests that:

32 psi test (based on RMA data)

Q-rated tires: 63.7 percent would have passed.  
R-rated tires: 90.7 percent would have passed.  
S-rated tires: 100 percent would have passed.

20 psi test based on NHTSA data

Q-rated tires: 25.0 percent would have passed.  
R-rated tires: 37.5 percent would have passed.  
S-rated tires: 70 percent would have passed.

## 1 INTRODUCTION

The Transportation Recall Enhancement, Accountability, and Documentation (T.R.E.A.D.) Act of 2000 mandates a rulemaking proceeding to revise and update our safety performance requirements for tires. In response to this mandate, NHTSA initiated a tire-testing program including a series of high-speed tests. The goal of these tests is to establish the maximum speed at which a tire can function without failure. The Rubber Manufacturers Association (RMA) has also provided test results from high-speed tests they have completed. This study analyzes the results of these high-speed tests. The primary measure used in this analysis is the speed-at-failure. This is the speed at which the tire is running when it fails<sup>2</sup>.

## 2 DISCUSSION

### 2.1 RMA High-speed Tests

The Rubber Manufacturers Association (RMA) provided results of high-speed tests of tires with Speed Rating<sup>3</sup> (SR) of S (180 km/h), T (190 km/h), and H (210 km/h) (included in Docket 8011, Entry#: 7). These tests were conducted at 180 kiloPascals (kPa) (26.1 psi), 240 kPa (34.8 psi), and 300 kPa (43.5 psi) inflation pressure. Test conditions used by RMA are described in Tables 1 and 2. The tires were subjected to a constant load equal to 80 and 90 percent of the tire's maximum load carrying capacity, as marked on sidewall. During these tests, the speed was incrementally increased until each tire failed.

Time (min)	Speed (km/h)
0 to 10	0 to ITS
10 to 20	ITS
20 to 30	ITS + 10
30 to 40	ITS + 20
40 to 50	ITS + 30
50 to 60	ITS + 40 (SR)*
*With an increment of 10km/h every 10 minutes until tire fails	

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<sup>1</sup> Failures include: tread chunking, belt-leaving-belt, blow-out, rupture, tread lifting, belt separation, tread / belt looseness, delaminating, etc. Failures may or may not involve air-loss.

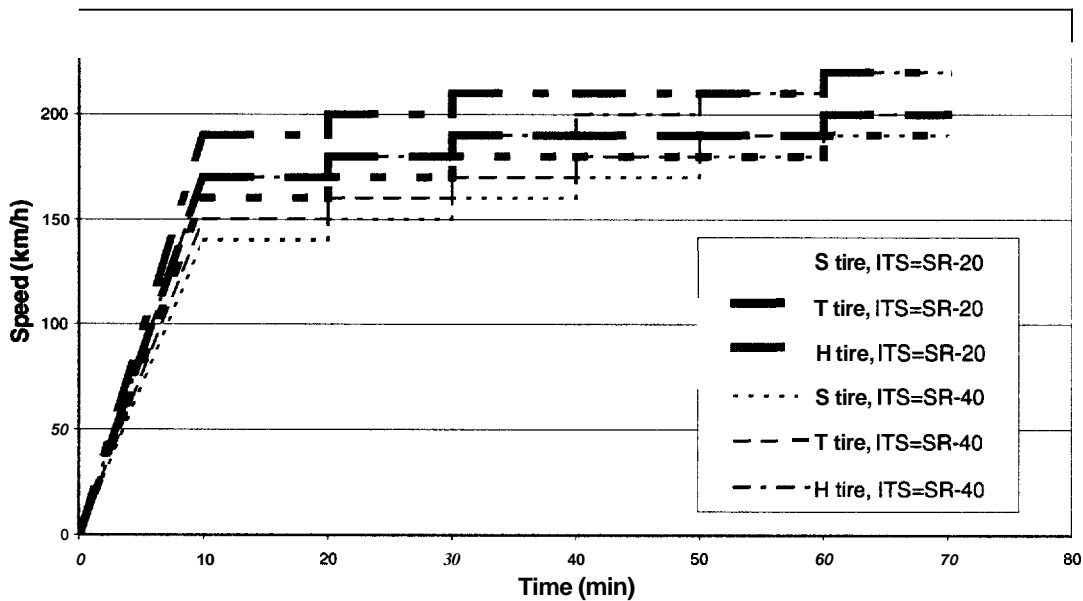
<sup>3</sup> The speed rating of a tire indicates the speed category (or range of speeds) at which the tire can carry a load under specified service conditions. The speed rating system used today was developed in Europe in response to the need to control the safe performance of tires at standardized speeds. A letter from A to Z symbolizes a tire's certified speed rating, ranging from 5 km/h (3 mph) to above 300 km/h (186 mph). This rating system describes the top speed for which a tire is certified. It does not indicate the total performance capability of a tire.

<sup>4</sup> ITS = Initial Test Speed

Time (min)	Speed (km/h)
0 to 10	0 to ITS
10 to 20	ITS
20 to 30	ITS + 10
30 to 60	ITS + 20 (SR)*

Figure 1, is a plot of step duration (minutes) vs. speed (km/h) showing the test conditions for the 'S', 'T', and 'H' type tires. In the first step, from 0 to 10 minutes, the test speed is increased from 0 to ITS. The test speed is then increased in increments of 10 km/h every 10 minutes until the tire fails. For the ITS-20 test condition the test speed is brought to ITS from zero in 10 minutes, then the test speed is incremented 10km/h every 10 minutes until the test speed reaches the SR, where it is allowed to run for 30 minutes. At the end of 30 minutes at the SR, the test speed is again incremented by 10km/h every 10 minutes until the tire fails. The time and the speed at which the tire fails were recorded.

Figure 1: RMA high speed test profile



The RMA data contains 14 test results for both speed and time-at-failure for each one of the test conditions. The specifications and the SR of tires tested by the RMA are the same type as those tested by NHTSA.

## 2.2 NHTSA High-speed Tests

Three subsets of tests were conducted. Five repetitions of the test for each tire brand were conducted. The results of the tests, including speed and time at failure, are included in Docket NHTSA-2000-8011.

### Subset A

NHTSA conducted high-speed tests of P-metric tires with Speed Ratings (SR) of 'S' (Category I), 'T' (Category II), and 'H' (Category III). These tests were conducted at 210 kPa (30 psi), and 220 kPa (32 psi) inflation pressure. During these tests, the speed was incrementally increased until each tire either failed or reached the rated speed of the tire. The tires tested were:

#### Category I: SR 'S' (180 km/h)

P235/75R15 (maximum load = 925 kg):

BF Goodrich Cienra Plus

Cooper LifeLiner Classic II

Firestone Wilderness AT

Michelin XH4

#### Category II: SR 'T' (190 km/h)

P205/65R15 (maximum load = 630 kg):

Dunlop D65 Touring

Goodyear Regatta

#### Category III: SR 'H' (210 km/h)

P225/60R16 (maximum load = 730 kg):

Toyo Proxes H4

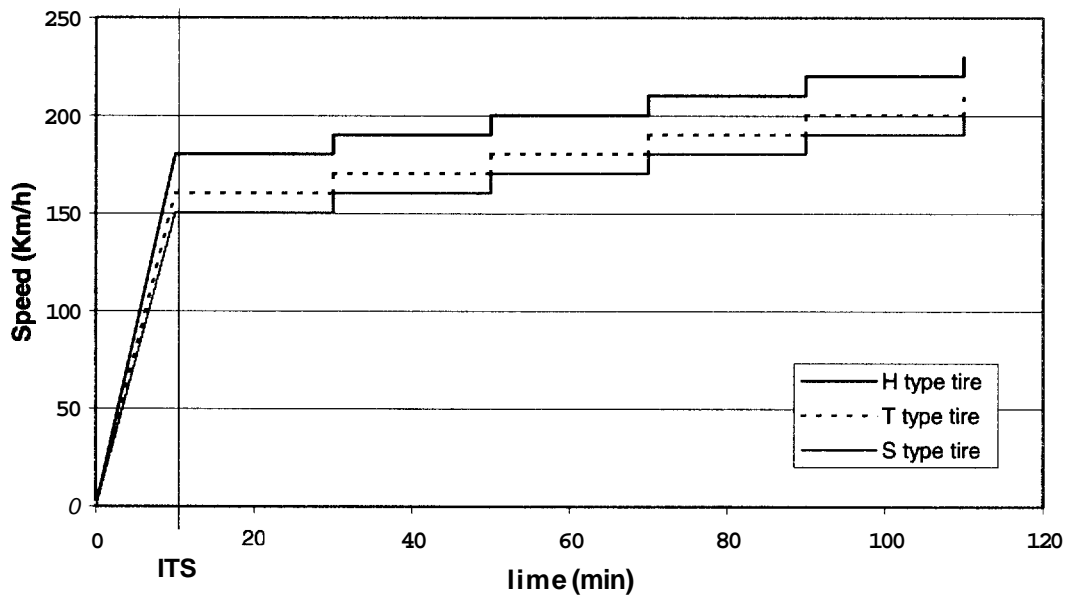
Uniroyal Tiger Paw Touring HR

The 'S', 'T', and 'H' type tires have maximum load specified on the sidewall of the tire of 925 kg, 630 kg, and 730 kg respectively. The tires were subjected to a load equal to 80 percent of maximum load for the 210 kPa (30 psi) tests and either 80 or 85 percent of maximum load for the 220 kPa (32 psi) tests. Throughout the experiment, the ambient temperature was maintained at a constant temperature, the load was held constant, and the inflation pressure was not adjusted to compensate for any changes due to heating.

The ITS for each tire was determined with respect to the SR of that tire and is given by  $ITS = SR - 30 \text{ km/h}$ . The speed profile for each condition is described in Table 3. Figure 2 is a plot of step duration (minutes) vs. speed (km/h) showing the test conditions for the 'S', 'T', and 'H' type tires. In the first step, the test speed is brought to the ITS from zero in a span of 10 minutes. Then, the tire is run at increasing increments of 10 km/h for every 20 minutes until the tire either fails or completes 20 minutes at the rated speed of the tire.

Time (min)	Speed (km/h)
0 to 10	0 to ITS
10 to 30	ITS
30 to 50	ITS + 10
50 to 70	ITS + 20
70 to 90	ITS + 30 (SR)*
* With an increment of 10km/h every 20 minutes until tire fails.	

**Figure 2: High-speed test profiles for NHTSA tests**

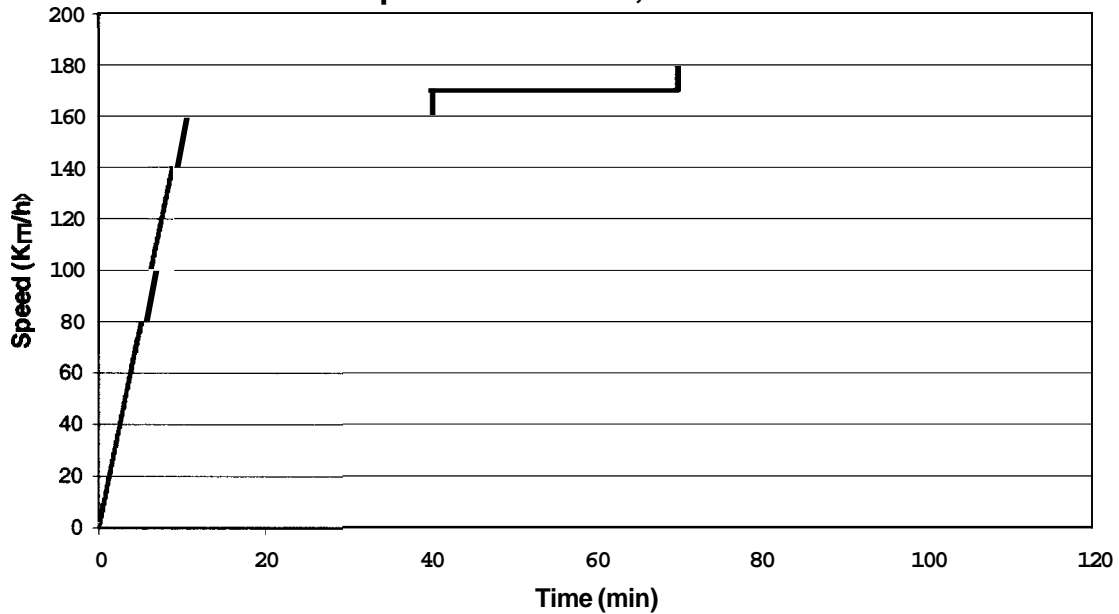


### Subset B

NHTSA conducted a separate high-speed test of the same types of tires used in Subset A at 210 kPa (30 psi) and 80 percent of maximum load. The speed profile for these tests is shown in Figure 3. During these tests, the speed was incrementally increased until each tire either failed or completed 30 minutes at 180km/h.



**Figure 3: High Speed test profiles for 160,170, and 180 km/h steps of 30 minutes, NHTSA tests**



### Subset C

The third set of NHTSA high-speed tests was run at **140 kPa** (20 psi), inflation pressure. The same types of tires used in Subset A were used for these tests. The speed profile for these tests was also the same as for Subset A, except that the speed was increased 10km/h for 20-minute increments above the speed rating of each tire. During these tests, the speed was incrementally increased until each tire failed.

Additional high speed testing has been done by NHTSA and the results are included in Docket NHTSA-2000-8011 (Entry 22). The results of these tests are not included in the analysis in this report because it was preliminary and only tested one sample of each type of tire.

## 23 Summary of Test Conditions

A Summary of test conditions for both the RMA and NHTSA high-speed tests is shown in Table 4.

**Table 4: Summary of Test Conditions**

Testing Agency	Pressure kPa (psi)	Percent Load	Test Condition	Test Completion Criteria
RMA	180 (26.1)	80 & 90	ITS = SR-40, SR-20	Tire failure
RMA	240 (34.8)	80 & 90	ITS = SR-40, SR-20	Tire failure
RMA	300 (43.5)	80 & 90	ITS = SR-40, SR-20	Tire failure
NHTSA	140 (20.3)	70	ITS = SR-30	Tire failure
NHTSA	210 (30.4)	80	ITS = SR-30	Test speed = SR or tire failure"
NHTSA	220 (31.9)	80	ITS = SR-30	Test speed = SR or tire failure"
NHTSA	210 (30.4)	80	160, 170, 180	Test speed = SR or tire failure"
NHTSA	220 (31.9)	85	ITS = SR-30	Test speed = SR or tire failure"

\* 'Test speed = **SR** or tire failure" indicates which ever occurs first

### 3 **PURPOSE OF ANALYSIS**

As outlined above both the RMA and NHTSA conducted high-speed tests by varying the following factors:

- Pressure,
- Load,
- Step duration, and
- Type of tire tested (based on Speed rating i.e. S, T, & H).

Test results from RMA and NHTSA are in the form of time-to-failure and speed-at-failure. This analysis attempts to address the relationship of the factors above with speed-at-failure of the tire. The significance of The Tire and **Rim** Association's (T&RA) "load formula" and the curve generated by using the formula (load curve) is also studied. (See Appendix 6.2) An understanding of the relationship between the tests conducted and the tire load or performance curve will help in determining specifications of test conditions for future tests.

## 4 **RESULTS**

### 4.1 **RMA Tests**

A histogram and cumulative percentage curve for each one of the test conditions in the RMA data set are shown in Figures 4 to 21.

Figure 4 illustrates failures at each speed step for an 'S' (SR) type tire inflated to 180 kPa (26 psi) with test conditions as described in Table 1 (ITS=SR-40). The mean speed-at-failure for this tire at this test condition occurs just above the tire SR of 180 km/h. The plot also demonstrates that most of tires fail at SR speed step.

Figure 5 illustrates failures at each speed step for an 'S' (SR) type tire inflated to 180 kPa (26 psi) with test conditions as described in Table 2 (ITS=SR-20). The mean speed-at-failure at this test condition occurs just below the tire's SR of 180 km/h.

Figure 6 illustrates failures at each speed step for a 'T' (SR) type tire inflated to **180 kPa (26 psi)** with test conditions as described in Table 1 (**ITS=SR-40**). The mean speed-at-failure for this tire at this test condition occurs at **195 km/h**, which is 5 km/h greater than its **SR of 190 km/h**. A majority of the tire failures occur at the **SR**.

Figure 7 illustrates failures at each speed step for a 'T' (SR) type tire inflated to **180 kPa (26 psi)** with test conditions as described in Table 2 (**ITS=SR-20**). The mean speed-at-failure for this test condition occurs just above the tire's **SR of 190 km/h**.

Figure 8 illustrates failures at each speed step for an 'H' (SR) type tire inflated to **180 kPa (26 psi)** with test conditions as described in Table 1 (**ITS=SR-40**). The mean speed-at-failure at this test condition occurs just above the tire's **SR of 210 km/h**.

Figure 9 illustrates failures at each speed step for an 'H' (SR) type tire inflated to **180 kPa (26 psi)** with test conditions as described in Table 2 (**ITS=SR-20**). The mean speed-at-failure for this test condition occurs at the tire's **SR 210 km/h**.

Figure 10 illustrates failures at each speed step for an 'S' (SR) type tire inflated to **240 kPa (35 psi)** with test conditions as described in Table 1 (**ITS=SR-40**). The mean speed-at-failure for this tire at this test condition occurs at **192 km/h**, which is one speed step (**10 km/h**) greater than its **SR of 180 km/h**. Therefore, an increase in inflation pressure by **60 kPa (9 psi)** with respect to the testing parameters in Figure 4 has resulted in an increase in speed-at-failure by **10 km/h** or one speed step in testing.

Figure 11 illustrates failures at each speed step for an 'S' (SR) type tire inflated to **240 kPa (35 psi)** with test conditions as described in Table 2 (**ITS=SR-20**). The mean speed-at-failure for this tire at this test condition occurs at **187 km/h**. An increase in inflation pressure by **60 kPa (9 psi)** with respect to the testing parameters in Figure 5 has resulted in an increase in speed-at-failure by **10 km/h** or one speed step in testing.

Figure 12 illustrates failures at each speed step for a 'T' (SR) type tire inflated to **240 kPa (35 psi)** with test conditions as described in Table 1 (**ITS=SR-40**). The mean speed-at-failure for this tire at this test condition occurs at **208 km/h**, which is one speed step (**10 km/h**) greater than its **SR of 190 km/h**. Therefore, an increase in inflation pressure by **60 kPa (9 psi)** with respect to the testing parameters in Figure 6 has resulted in an increase in speed-at-failure by **10 km/h** or one speed step in testing.

Figure 13 illustrates failures at each speed step for a 'T' (SR) type tire inflated to **240 kPa (35 psi)** with test conditions as described in Table 2 (**ITS=SR-20**). The mean speed-at-failure for this tire at this test condition occurs at **205 km/h**, which is one speed step (**10 km/h**) greater than its **SR of 190 km/h**. Therefore, an increase in inflation pressure by **60 kPa (9 psi)** with respect to the testing parameters in Figure 7 has resulted in an increase in speed-at-failure by **10 km/h** or one speed step in testing.

Figure 14 illustrates failures at each speed step for an 'H' (SR) type tire inflated to **240 kPa (35 psi)** with test conditions as described in Table 1 (**ITS=SR-40**). The mean

speed-at-failure for this tire at this test condition occurs at **230 km/h**, which is two speed steps (**20 km/h**) greater than its **SR** of **210 km/h**. Therefore, an increase in inflation pressure by **60 kPa (9 psi)** with respect to the testing parameters in Figure 8 has resulted in an increase in speed-at-failure by **20 km/h** or two speed steps in testing.

Figure 15 illustrates failures at each speed step for an ‘H’ (SR) type tire inflated to **240 kPa (35 psi)** with test conditions as described in Table 2 (ITS=SR-20). The mean speed-at-failure for this tire, at this test condition, occurs at **230 km/h**, which is two speed steps (**20 km/h**) greater than its **SR** of **210 km/h**. Therefore, an increase in inflation pressure by **60 kPa (9 psi)** with respect to the testing parameters in Figure 9 has resulted in an increase in speed-at-failure by **20 km/h** or two speed steps in testing.

Figure 16 illustrates failures at each speed step for an ‘S’ (SR) type tire inflated to **300 kPa (44 psi)** with test conditions as described in Table 1 (ITS=SR-40). The mean speed-at-failure for this tire at this test condition occurs at **201 km/h**, which is two speed steps (**20 km/h**) greater than its **SR** of **180 km/h**. Therefore, an increase in inflation pressure by **120 kPa (18 psi)** with respect to the testing parameters in Figure 4 has resulted in an increase in speed-at-failure by **20 km/h** or two speed steps in testing.

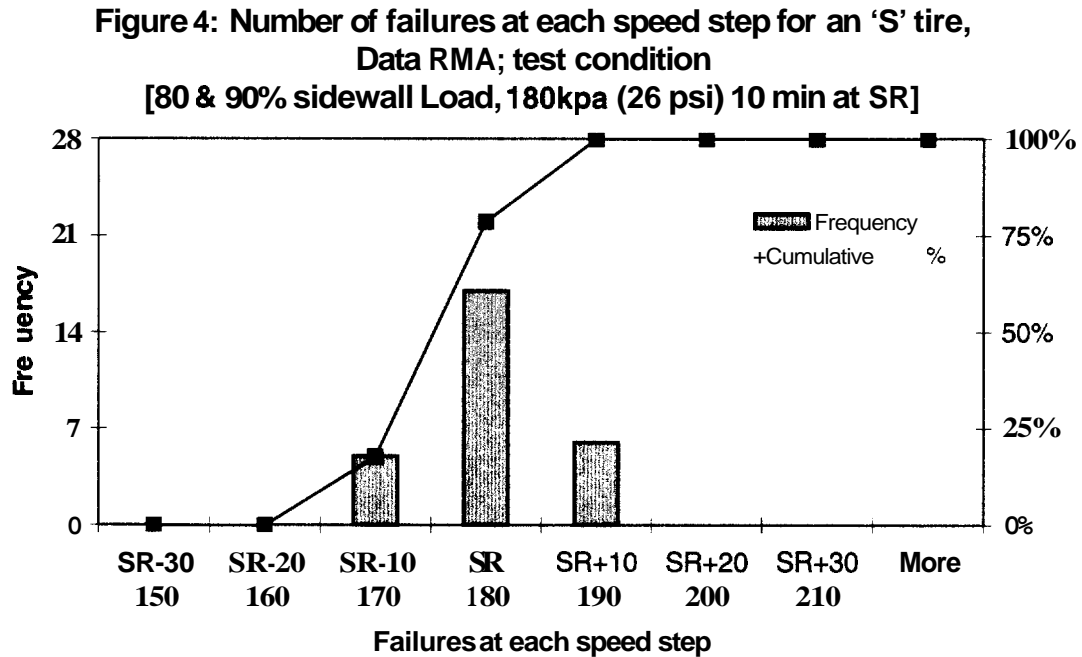
Figure 17 illustrates failures at each speed step for an ‘S’ (SR) type tire inflated to **300 kPa (44 psi)** with test conditions as described in Table 2 (ITS=SR-20). The mean speed-at-failure for this tire at this test condition occurs at **201 km/h**, which is two speed steps (**20 km/h**) greater than its **SR** of **180 km/h**. Therefore, an increase in inflation pressure by **120 kPa (18 psi)** with respect to the testing parameters in Figure 5 has resulted in an increase in speed-at-failure by **20 km/h** or two speed steps in testing.

Figure 18 illustrates failures at each speed step for a ‘T’ (SR) type tire inflated to **300 kPa (44 psi)** with test conditions as described in Table 1 (ITS=SR-40). The mean speed-at-failure for this tire at this test condition occurs at **217 km/h**, which is two speed steps (**20 km/h**) greater than its **SR** of **190 km/h**. Therefore, an increase in inflation pressure by **120 kPa (18 psi)** with respect to the testing parameters in Figure 6 has resulted in an increase in speed-at-failure by **20 km/h** or two speed steps in testing.

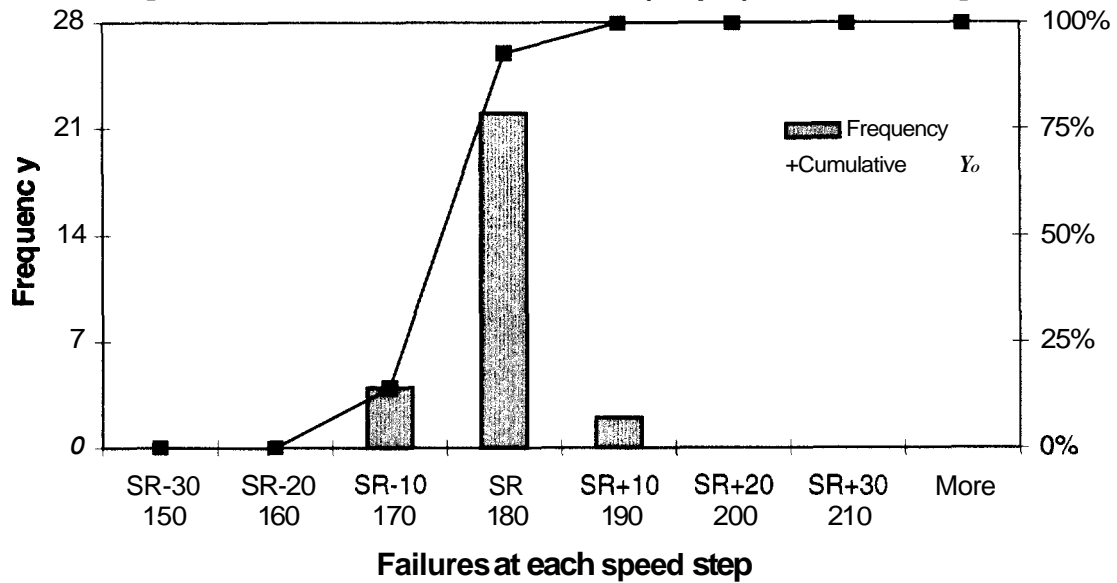
Figure 19 illustrates failures at each speed step for a ‘T’ (SR) type tire inflated to **300 kPa (44 psi)** with test conditions as described in Table 2 (ITS=SR-20). The mean speed-at-failure for this tire at this test condition occurs at **216 km/h**, which is two speed steps (**20 km/h**) greater than its **SR** of **190 km/h**. Therefore, an increase in inflation pressure by **120 kPa (18 psi)** with respect to the testing parameters in Figure 7 has resulted in an increase in speed-at-failure by **20 km/h** or two speed steps in testing.

Figure 20 illustrates failures at each speed step for an ‘H’ (SR) type tire inflated to **300 kPa (44 psi)** with test conditions as described in Table 1 (ITS=SR-40). The mean speed-at-failure for this tire at this test condition occurs at **245 km/h**, which is three speed steps (**30 km/h**) greater than its **SR** of **210 km/h**. Therefore, an increase in inflation pressure by **120 kPa (18 psi)** with respect to the testing parameters in Figure 8 has resulted in an increase in speed-at-failure by **30 km/h** or three speed steps in testing.

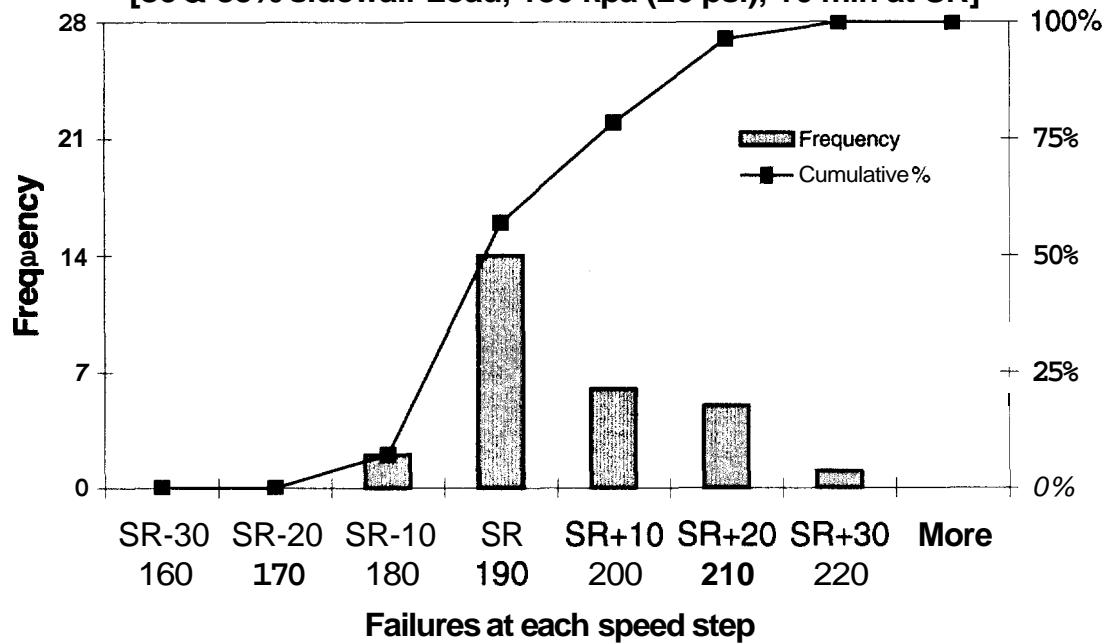
Figure 21 illustrates failures at each speed step for an 'H' (SR) type tire inflated to 300 kPa (44 psi) with test conditions as described in Table 2 (ITS=SR-20). The mean speed-at-failure for this tire at this test condition occurs at 245 km/h, which is three speed steps (30 km/h) greater than its SR of 210 km/h. Therefore, an increase in inflation pressure by 120 kPa (18 psi) with respect to the testing parameters in Figure 9 has resulted in an increase in speed-at-failure by 30 km/h or three speed steps in testing.



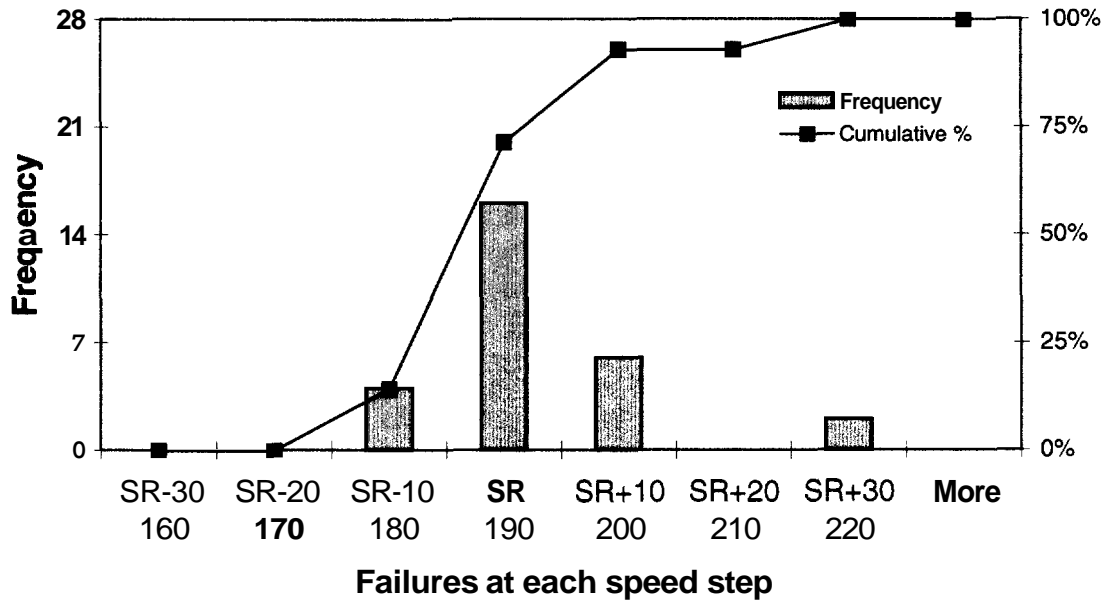
**Figure 5: Number of failures at each speed step for an 'S' tire, Data RMA; test conditions: [80 & 90% sidewall Load, 180kpa (26 psi), 30 min at SR]**



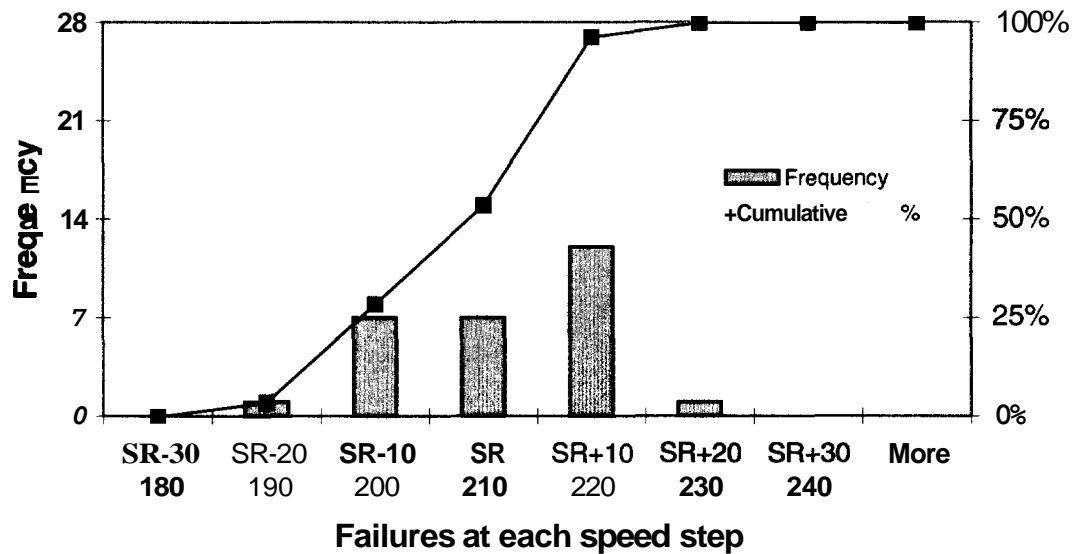
**Figure 6: Number of failures at each speed step for a 'T' tire, Data RMA; test condition [80 & 90% sidewall Load, 180 kpa (26 psi), 10 min at SR]**



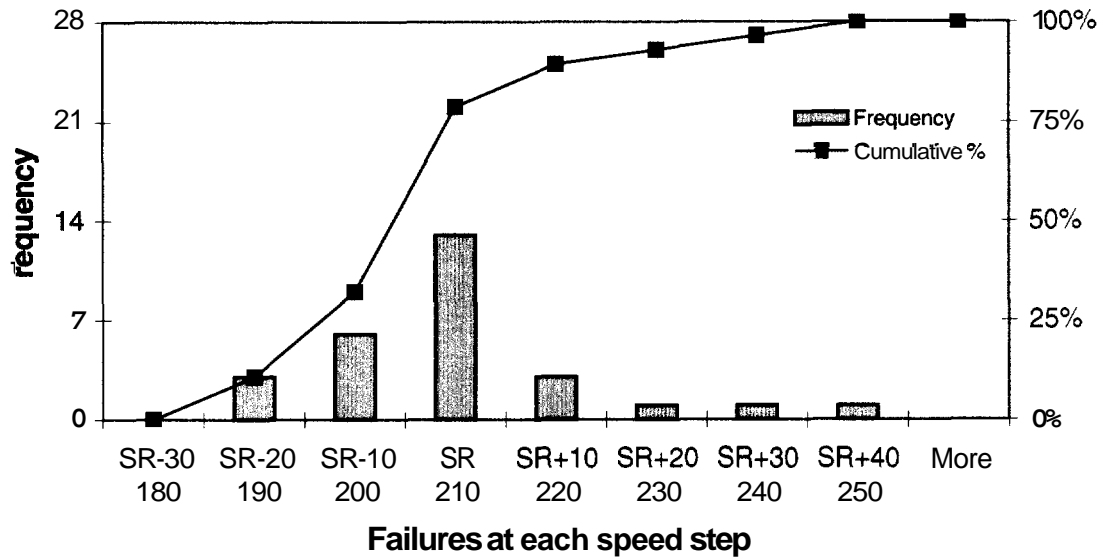
**Figure 7: Number of failures at each speed step for a 'T' tire, Data RMA; test condition [80 & 90% sidewall Load, 180 kpa (26 psi), 30 min at SR]**



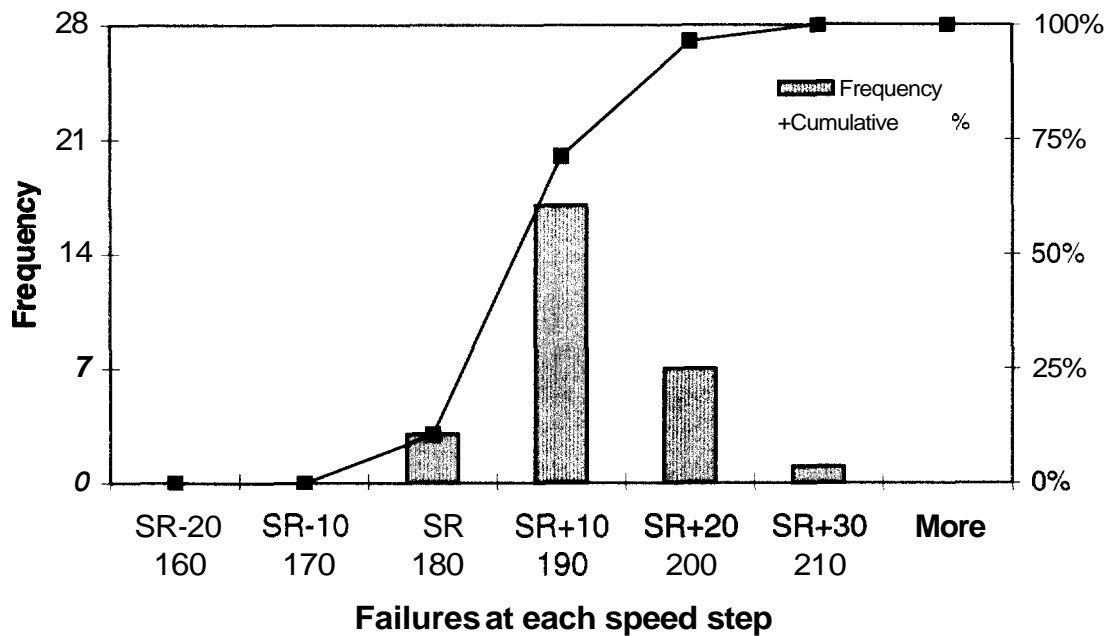
**Figure 8: Number of failures at each speed step for an 'H' tire, Data RMA; test condition [80 & 90% sidewall Load, 180 kpa (26 psi), 10 min at SR]**



**Figure 9: Number of failures at each speed step for an 'H' tire, Data RMA; test condition**  
**[80& 90% sidewall Load, 180 kpa (26 psi), 30 min at SR]**

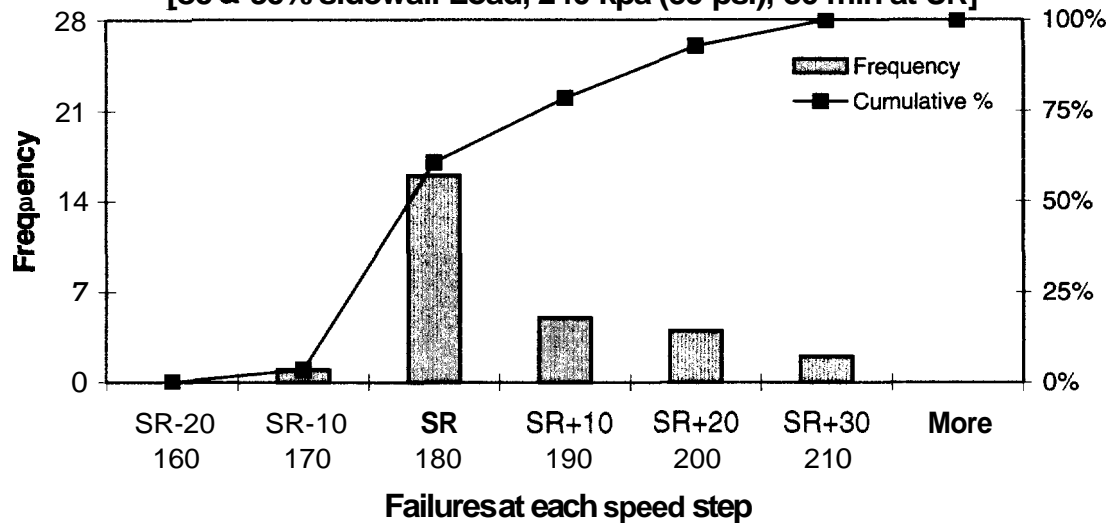


**Figure 10: Number of failures at each speed step for an 'S' tire, Data RMA; test condition**  
**[80 & 90% sidewall Load, 240 kpa (35 psi), 10 min at SR]**

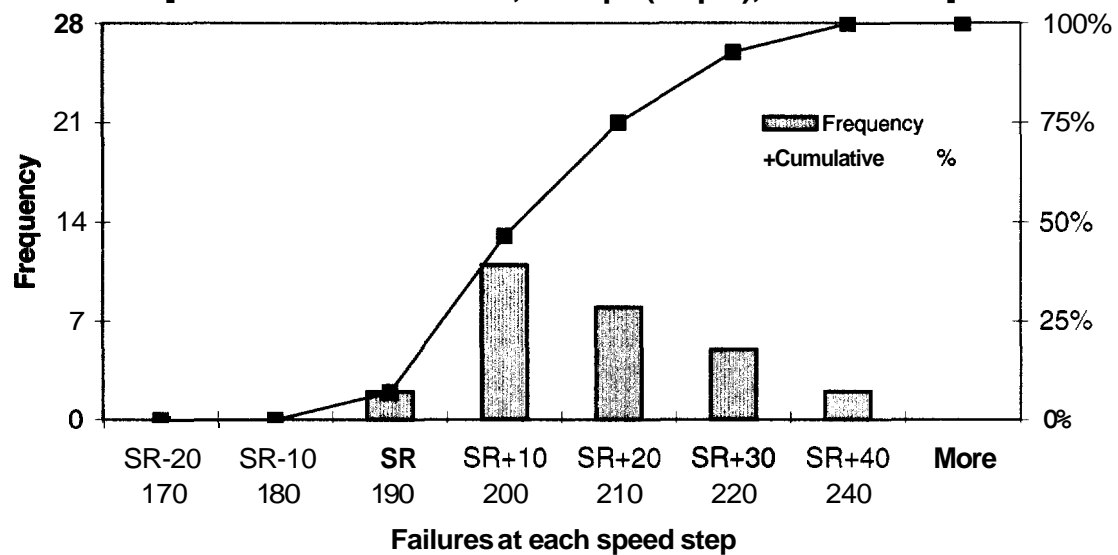




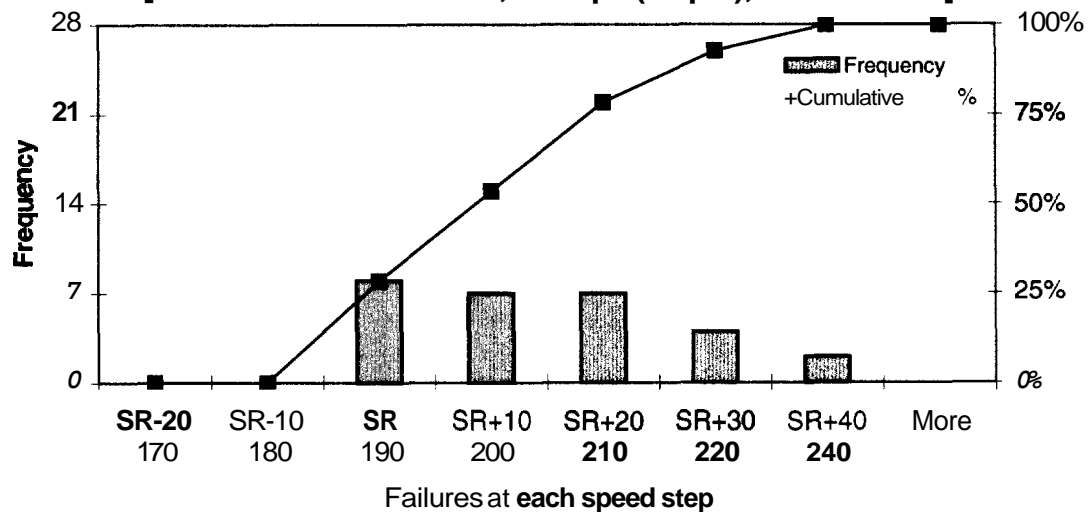
**Figure 11: Number of failures at each speed step for an 'S' tire, Data RMA; test condition**  
**[80 & 90% sidewall Load, 240 kpa (35 psi), 30 min at SR]**



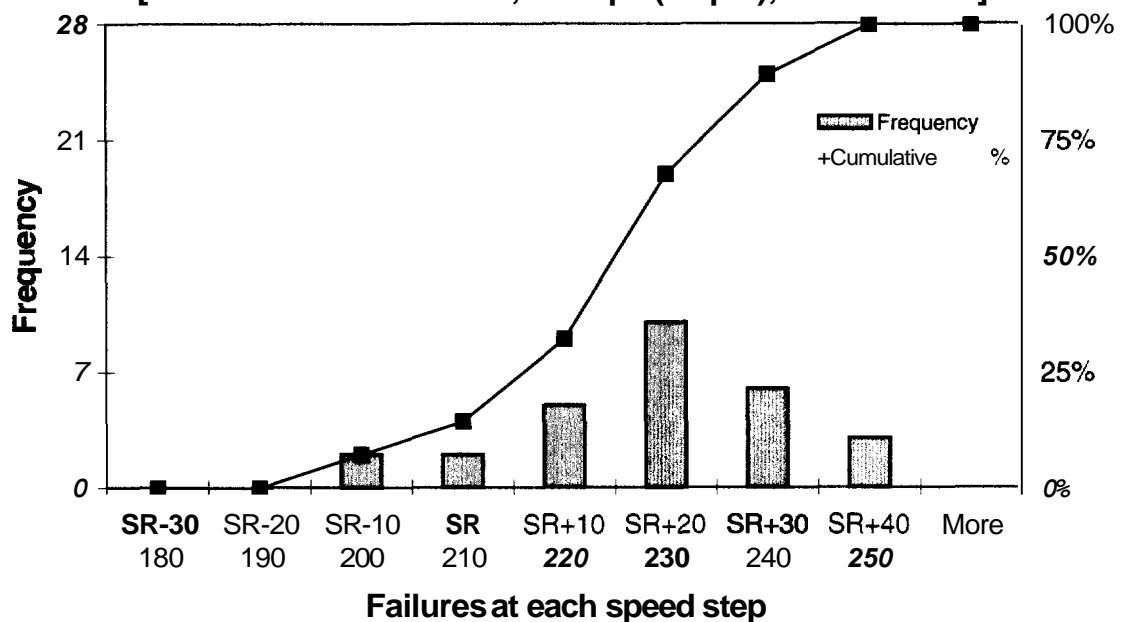
**Figure 12: Number of failures at each speed step for a 'T' tire, Data RMA; test condition**  
**[80 & 90% sidewall Load, 240 kpa (35 psi), 10 min at SR]**



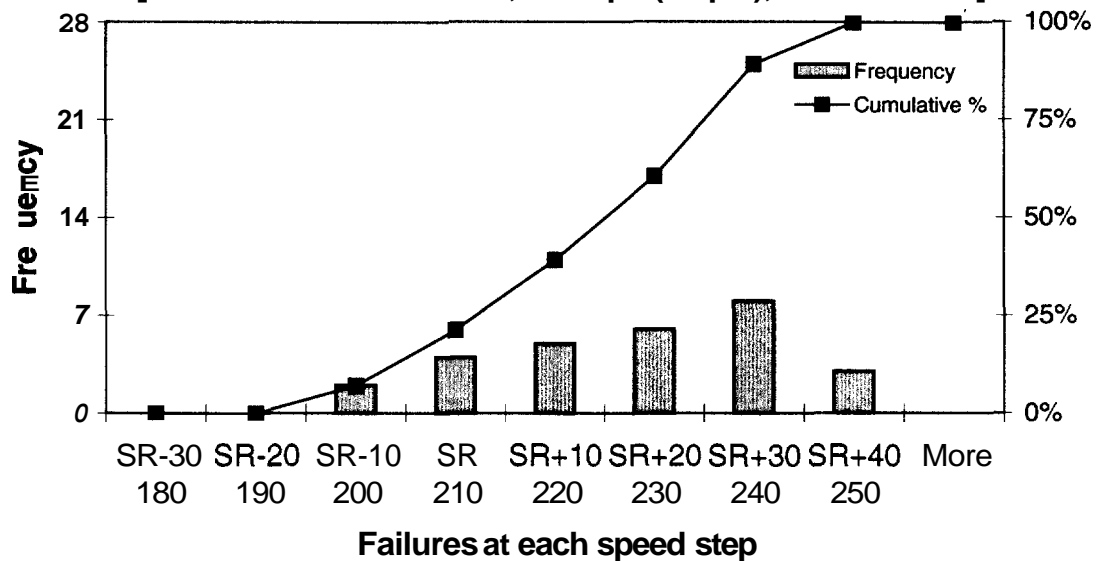
**Figure 13: Number of failures at each speed step for a 'T' tire,  
Data RMA; test condition  
[80 & 90% sidewall Load, 240 kpa (35 psi), 30 min at SR]**



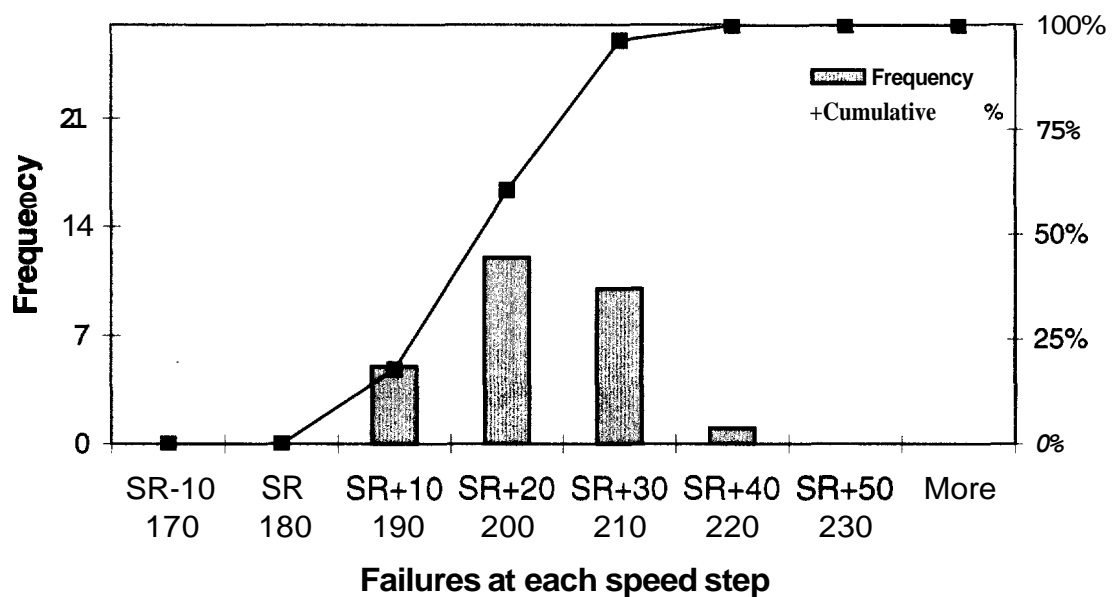
**Figure 14: Number of failures at each speed step for an 'H' tire, Data RMA; test condition  
[80 & 90% sidewall Load, 240 kpa (35 psi), 10 min at SR]**



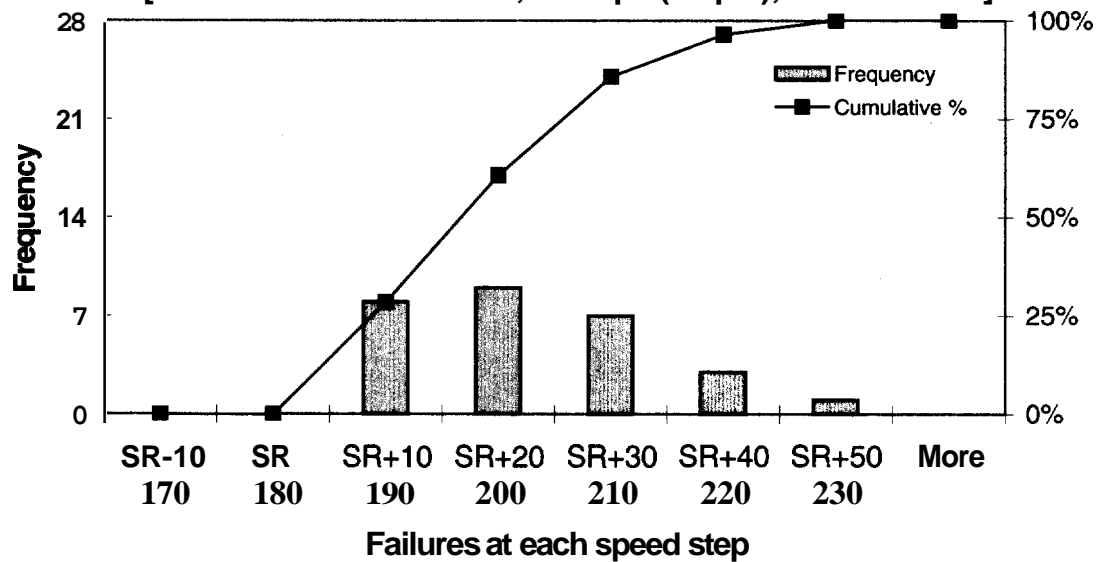
**Figure 15: Number of failures at each speed step for an 'H' tire, Data RMA; test condition [80 & 90% sidewall Load, 240 kpa (35 psi), 30 min at SR]**



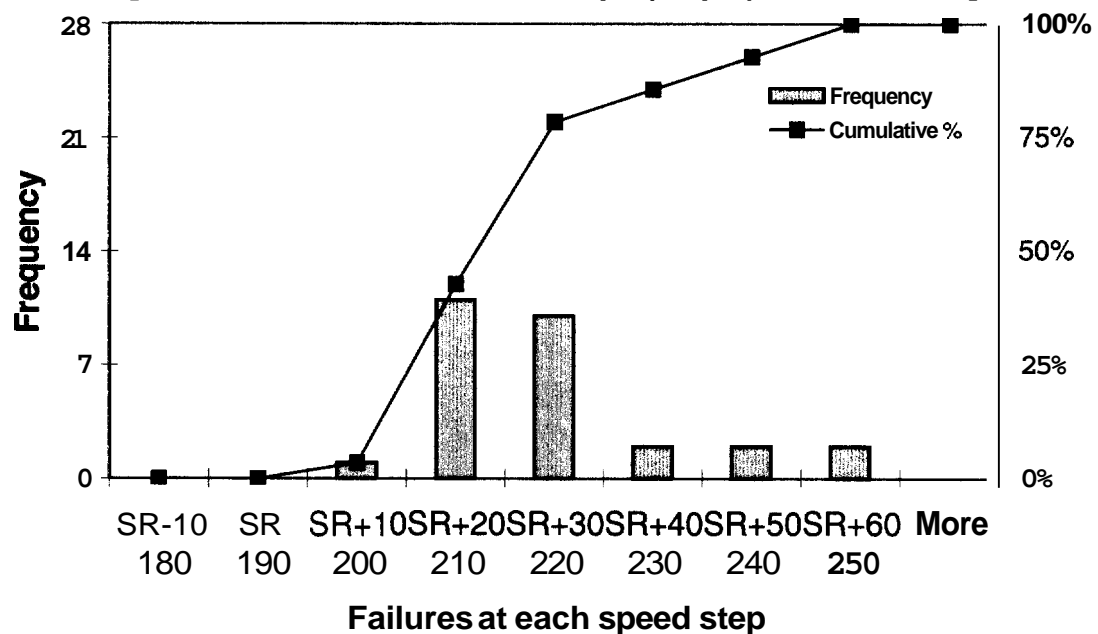
**Figure 16: Number of failures at each speed step for an 'S' tire, Data RMA; test condition [80 & 90% sidewall Load, 300 kpa (44 psi), 10 min at SR]**



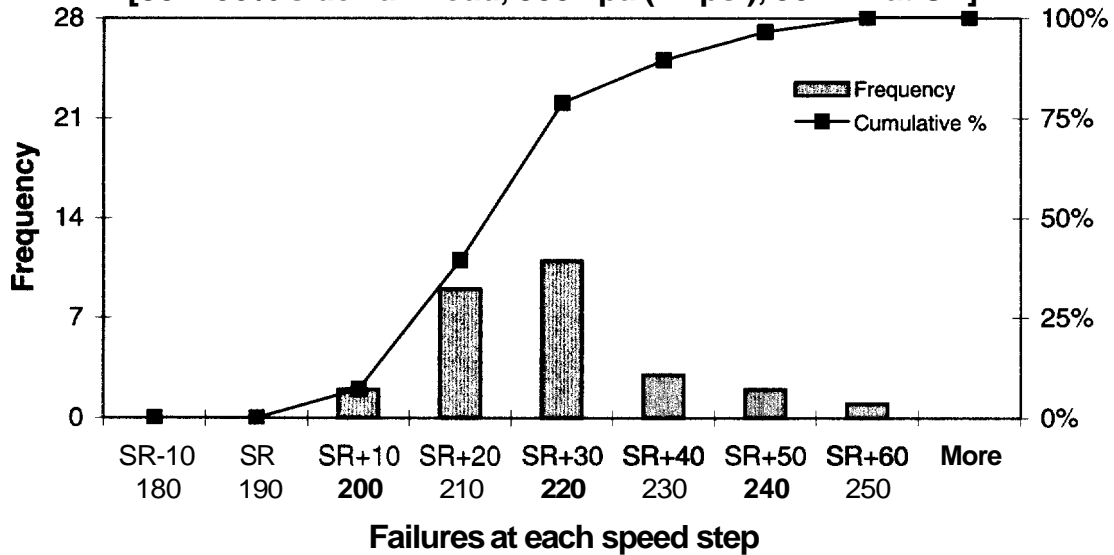
**Figure 17: Number of failures at each speed step for an 'S' tire, Data RMA; test condition [80 & 90% sidewall Load, 300 kpa (44 psi), 30 min at SR]**



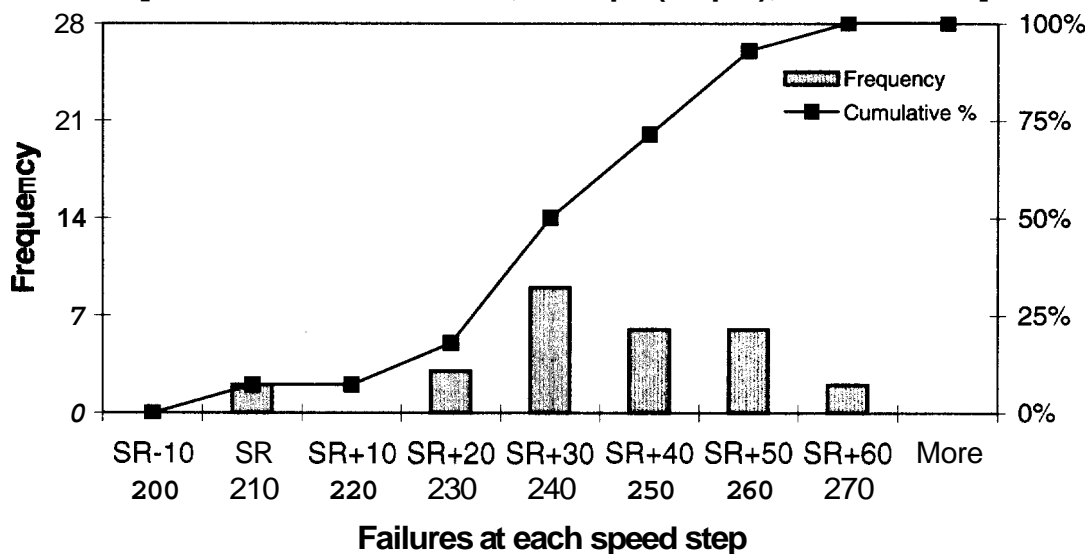
**Figure 18: Number of failures at each speed step for a 'T' tire, Data RMA; test condition [80 & 90% sidewall Load, 300 kpa (44 psi), 10 min at SR]**



**Figure 19: Number of failures at each speed step for a 'T' tire, Data RMA; test condition [80 & 90% sidewall Load, 300 kpa (44 psi), 30 min at SR]**



**Figure 20: Number of failures at each speed step for an 'H' tire, Data RMA; test condition [80 & 90% sidewall Load, 300 kpa (44 psi), 10 min at SR]**



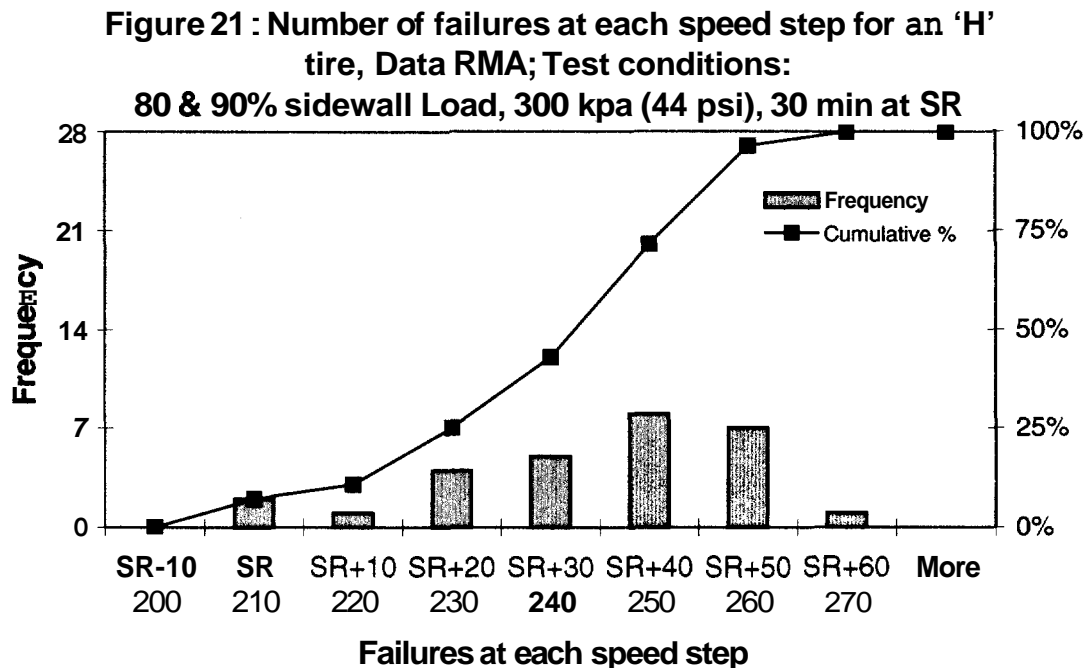


Figure 22 illustrates a histogram of the mean speed-at-failure for a 'T' tire at 3 levels of inflation pressure: 180, 240, and 300 kPa, as tested by RMA. The four bars at each pressure level indicate the mean speed-at-failure for test conditions (1) ITS-40, 80 percent sidewall Load, and 10 min at SR; (2) ITS-40, 90 percent sidewall load, and 10 min at SR; (3) ITS-20, 80 percent sidewall load, and 30 min at SR (4) ITS-20, 90 percent sidewall load, and 30 min at sidewall load.

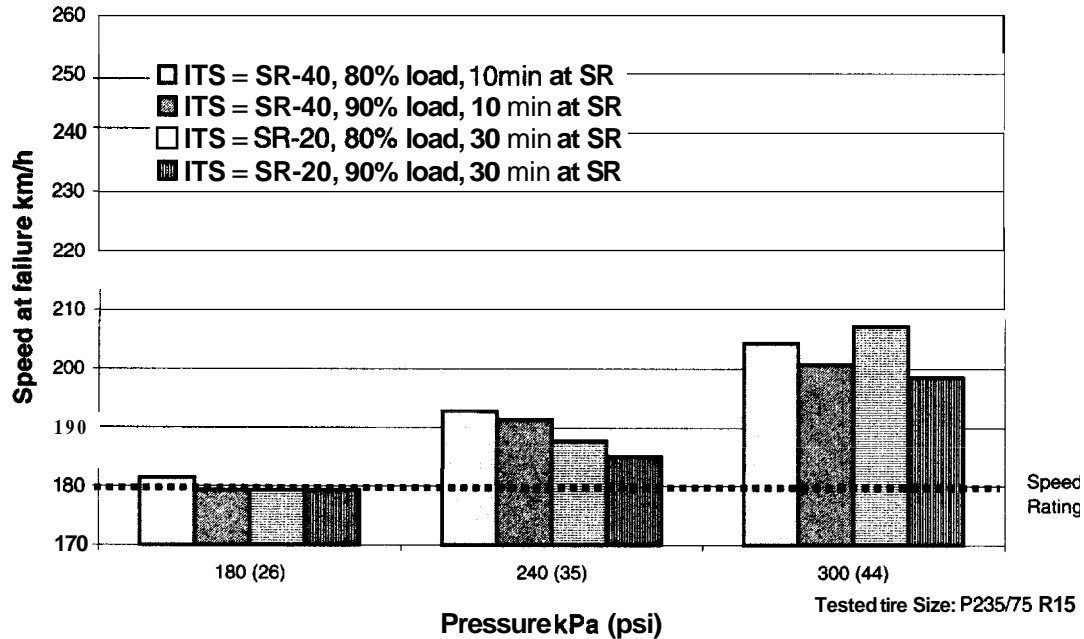
An increase of 60 kPa (9 psi) in the inflation pressure results in an increase in speed-at-failure by 10 km/h, keeping all other test conditions constant for an 'S' tire (Figure 21). Most of the tires fail or just make it to the SR of 180 km/h at 180 kPa (26 psi) inflation pressure. At a sidewall pressure of 35 psi, most of the tires have speed-at-failure equal to or better than the SR. Finally, at the 44 psi inflation pressure, which is greater than the maximum inflation pressure specified on the sidewall for P-metric tires, the tires run 20 km/h faster than the SR before failure.

Figure 23 illustrates the mean speed-at-failure, at an inflation pressure of 180 kPa (26 psi), is 195 km/h, which is about 5 km/h above the SR for a 'T' type tire. Similar to an 'S' tire, the mean speed-at-failure for the 'T' type tire also increases by 12 km/h for each increase in inflation pressure by 60 kPa (9 psi).

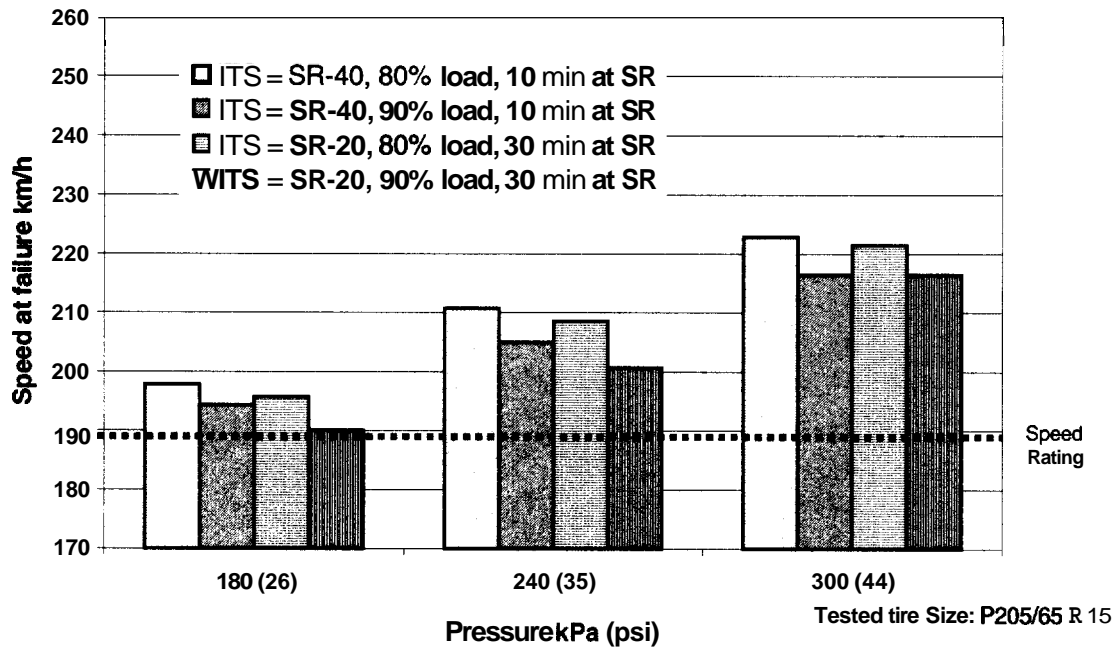
Figure 24 illustrates a histogram of the mean speed-at-failure for 'H' tires at 3 levels of inflation pressure 180, 240, and 300 kPa, tested by RMA. The mean speed-at-failure, at 180 kPa (26 psi) inflation pressure, is 211 km/h, which is 1 km/h above the SR for 'H' type tire. Similar to 'S' and 'T' tires, the mean speed-at-failure for the 'H' type

tire also increases by 12 km/h for each increase in inflation pressure by 60 kPa (9 psi). The mean speed at 240 kPa is 228 km/h and at 300 kPa, it is 245 km/h.

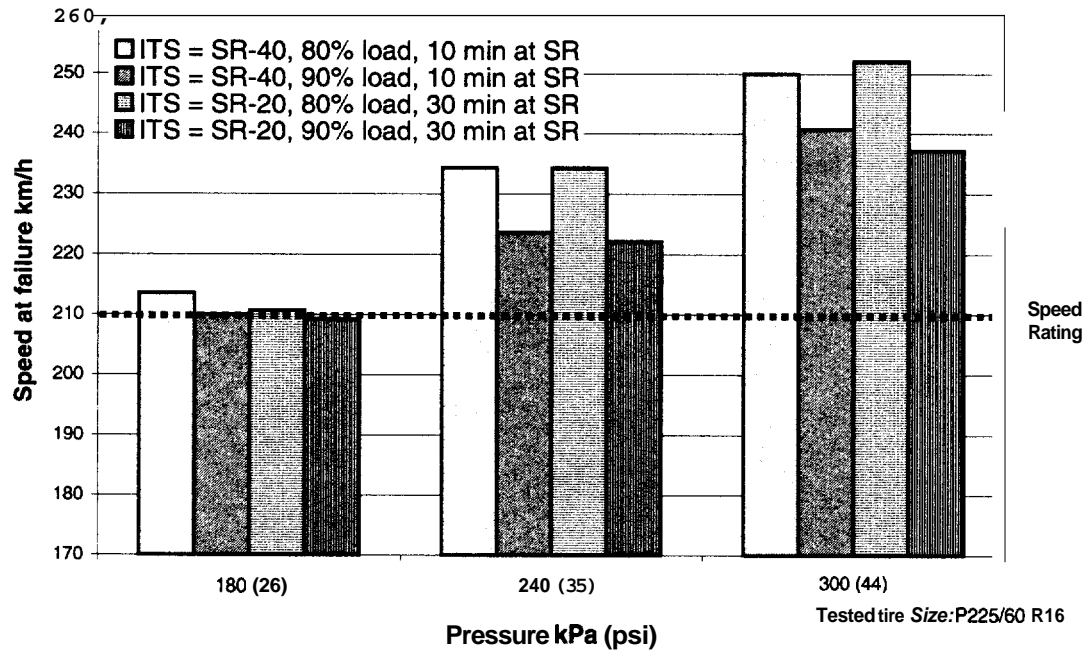
**Figure 22: Average speed at failure, RMA Data  
SR = 'S' (180km/h)**



**Figure 23: Average speed at failure, RMA Data  
SR = 'T' (190km/h)**



**Figure 24: Average speed at failure, RMA Data**  
**SR = 'H' (210km/h)**



## 4.2 NHTSA Tests

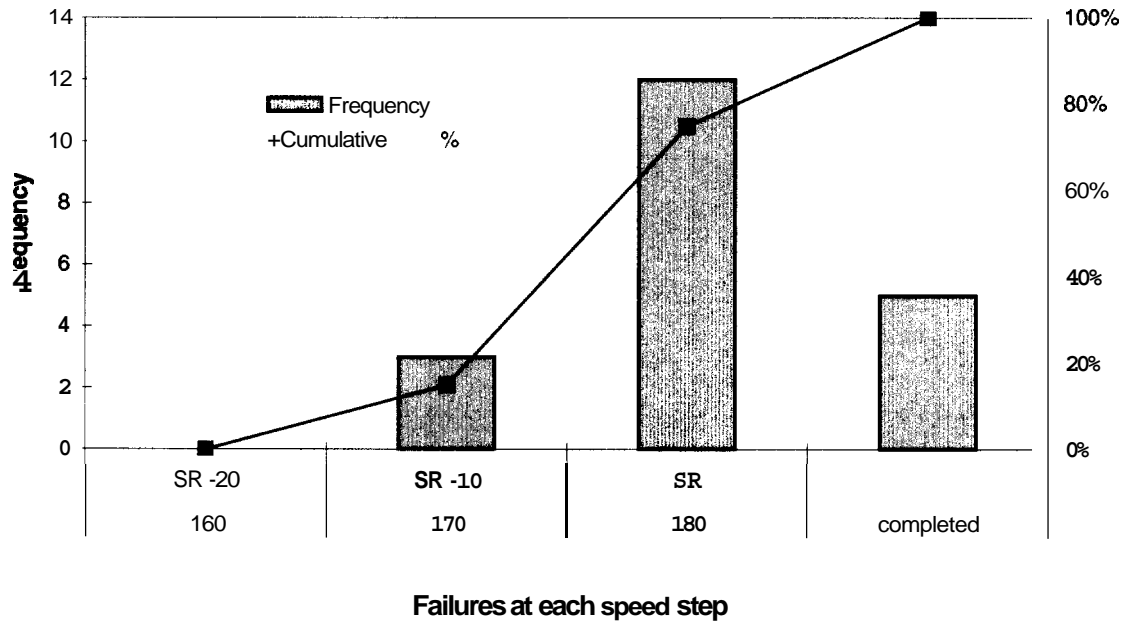
Section 2.2 of this report describes the NHTSA tests of high-speed performance of passenger vehicle tires. The test results are provided in Docket NHTSA-2000-8011.

### Tests at 210/220 kPa and 80/85% of maximum load (Subset A)

In this series of tests, tires were tested to either completion of a 20 minute segment at the rated speed of the tire or tire failure, whichever came first. The distribution of time-to-failure, for the tires that failed during the test, is shown in Figures 25-33.



**Figure 25: Number of failures at each speed step for a 'S' tire,  
data NHTSA  
[80% sidewall Load, 210 kPa (31 psi), steps 20min]**



**Figure 26: Number of failures at each speed step for a 'T' tire,  
data NHTSA  
[80% sidewall Load, 210 kPa (31 psi), steps 20min]**

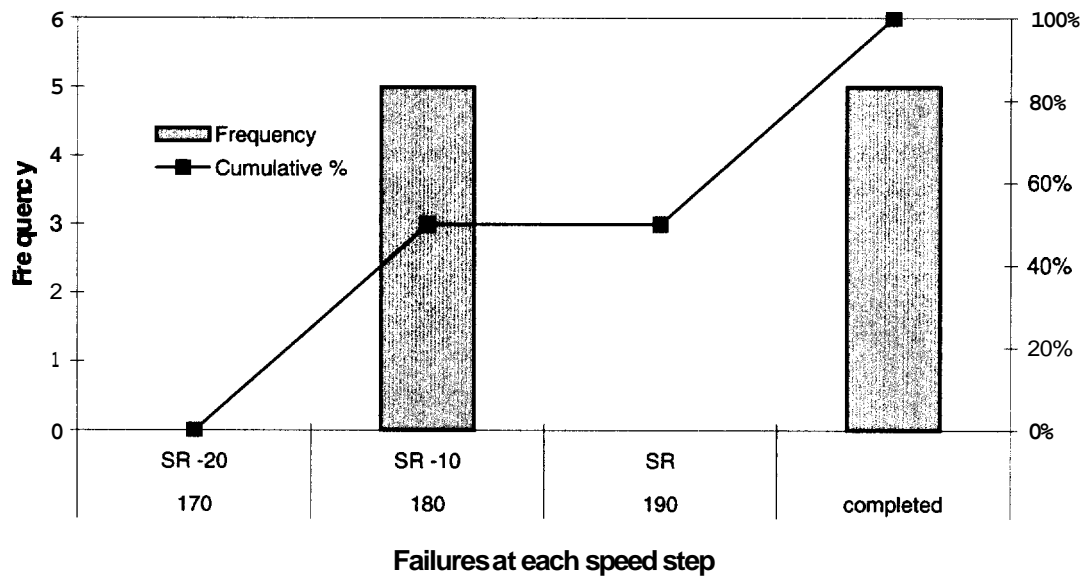


Figure 27: Number of failures at each speed step for a 'H' tire,  
data NHTSA  
[80% sidewall Load, 210 kPa (31psi), steps 20min]

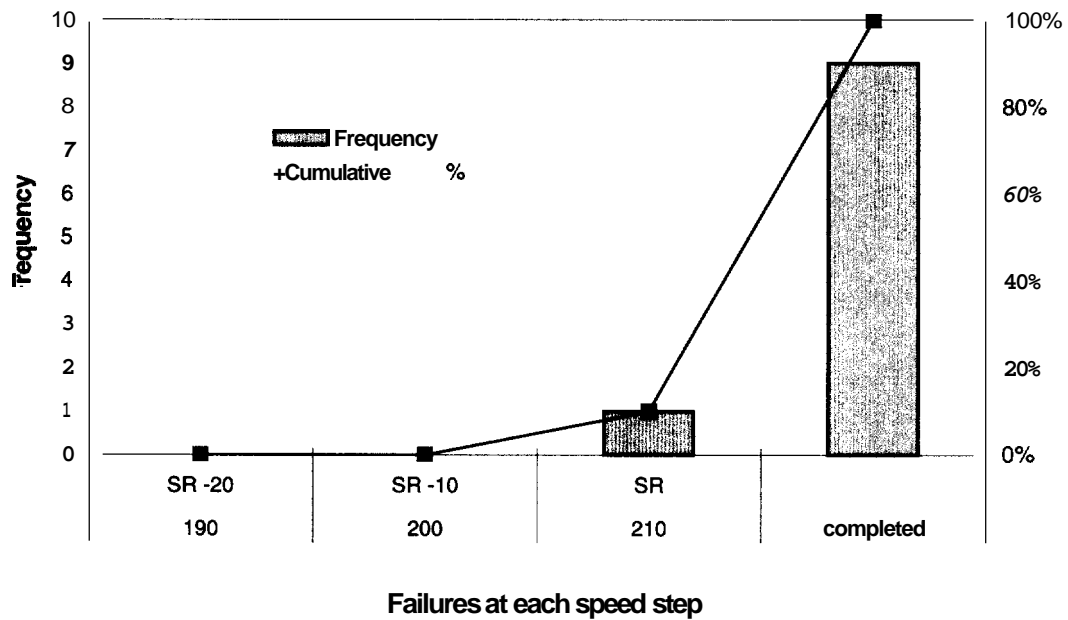
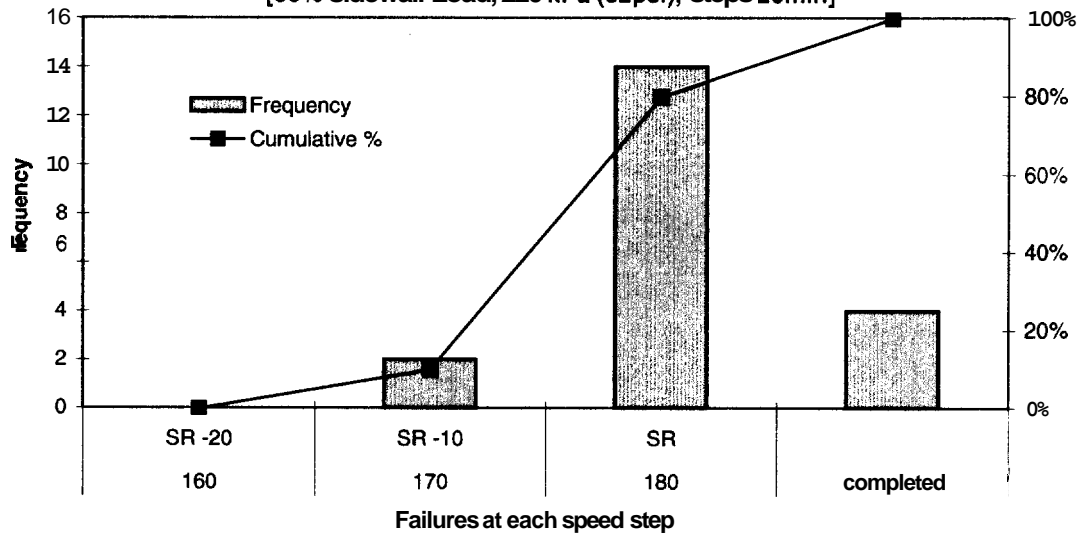
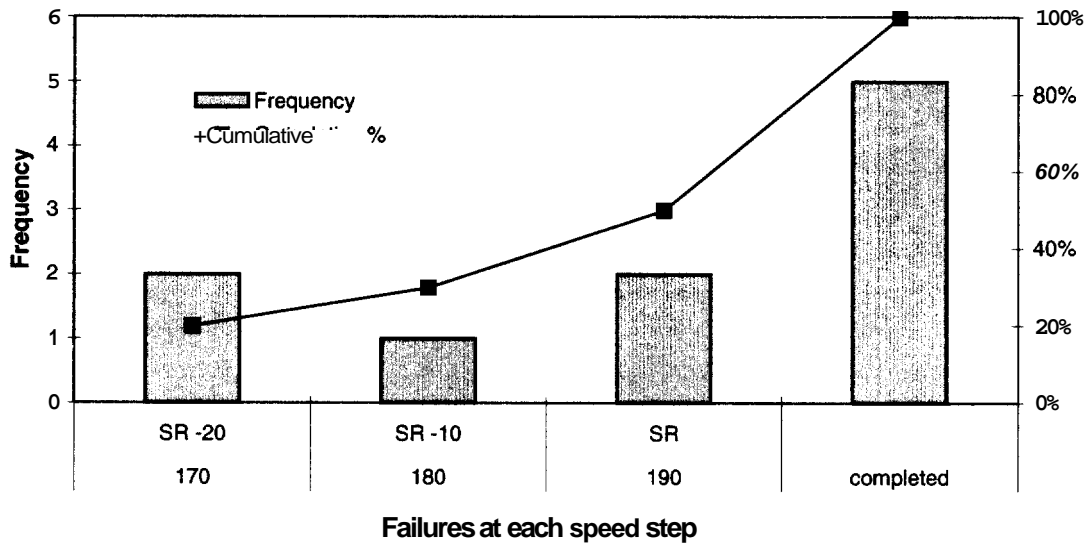


Figure 28: Number of failures at each speed step for a 'S' tire,  
data NHTSA  
[80% sidewall Load, 220 kPa (32psi), steps 20min]



**Figure 29: Number of failures at each speed step for a 'T' tire,  
data NHTSA  
[80% sidewall Load, 220 kPa (32psi), steps 20min]**



**Figure 30: Number of failures at each speed step for a 'H' tire,  
data NHTSA  
[80% sidewall Load, 220 kPa (32psi), steps 20min]**

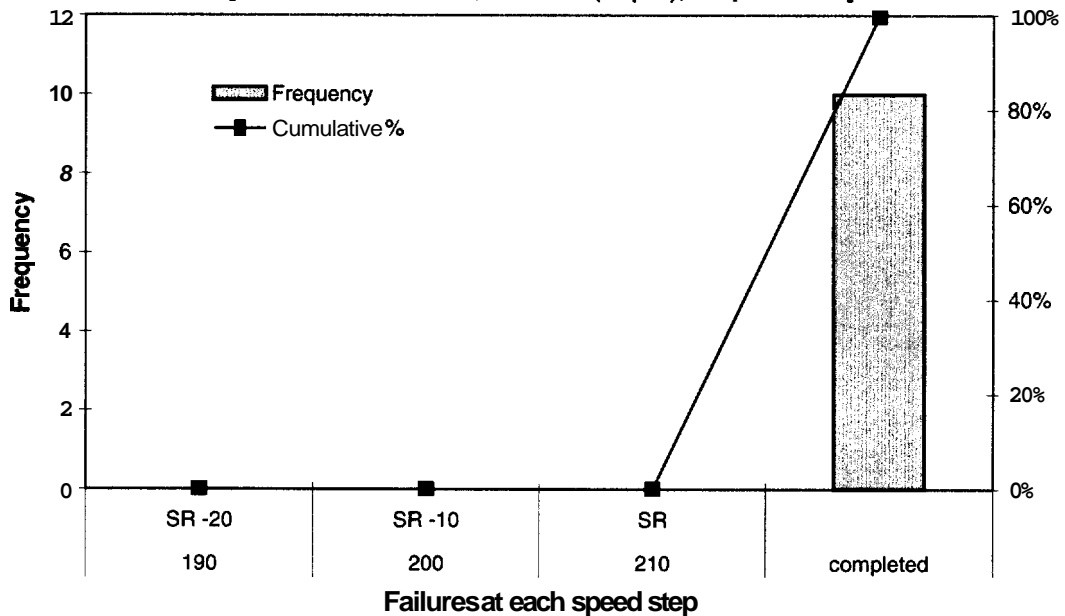


Figure 31: Number of failures at each speed step for a 'S' tire,  
data NHTSA  
[85% sidewall Load, 220 kPa (32psi), steps 20min]

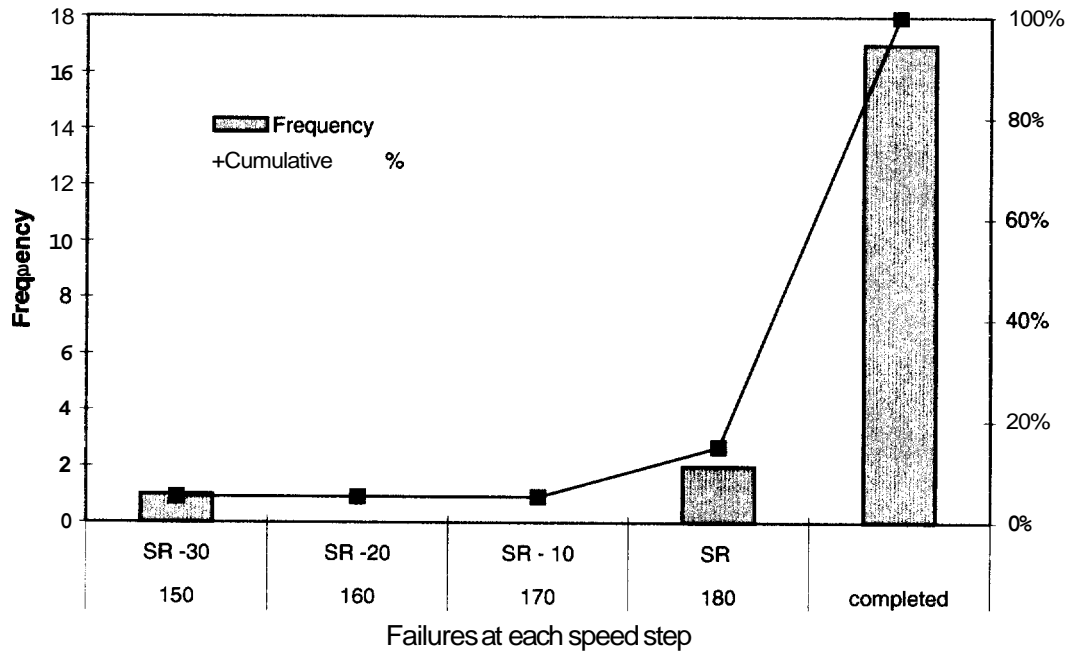


Figure 32: Number of failures at each speed step for a 'T' tire,  
data NHTSA  
[85% sidewall Load, 220 kPa (32psi), steps 20min]

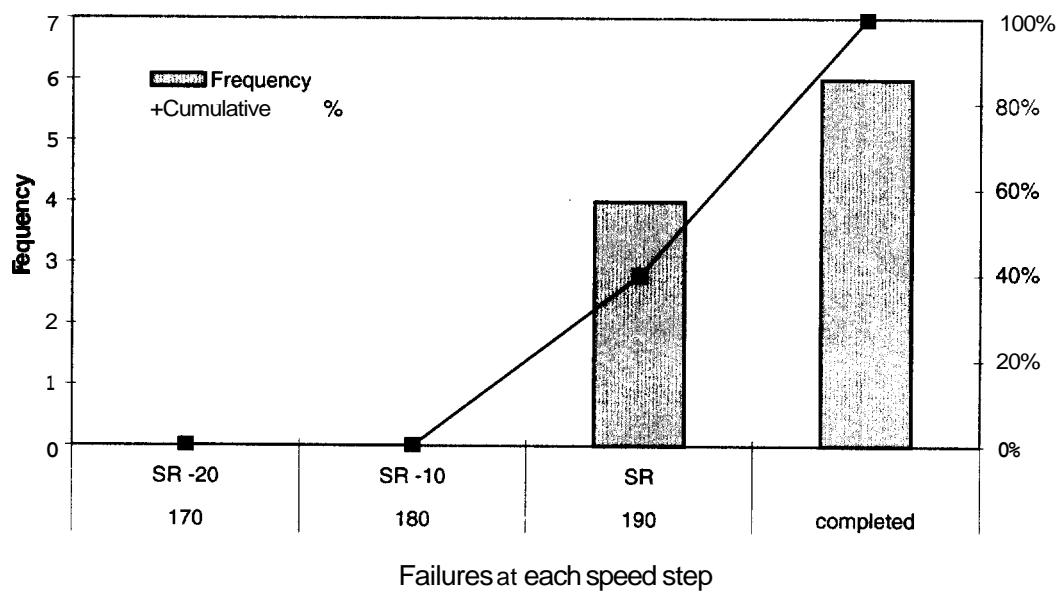
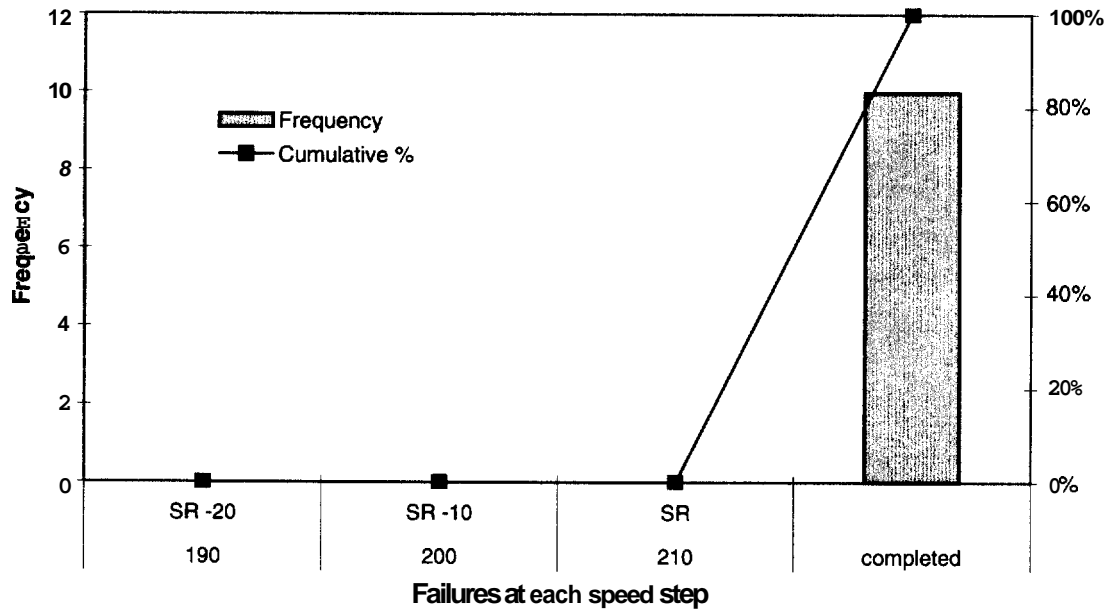


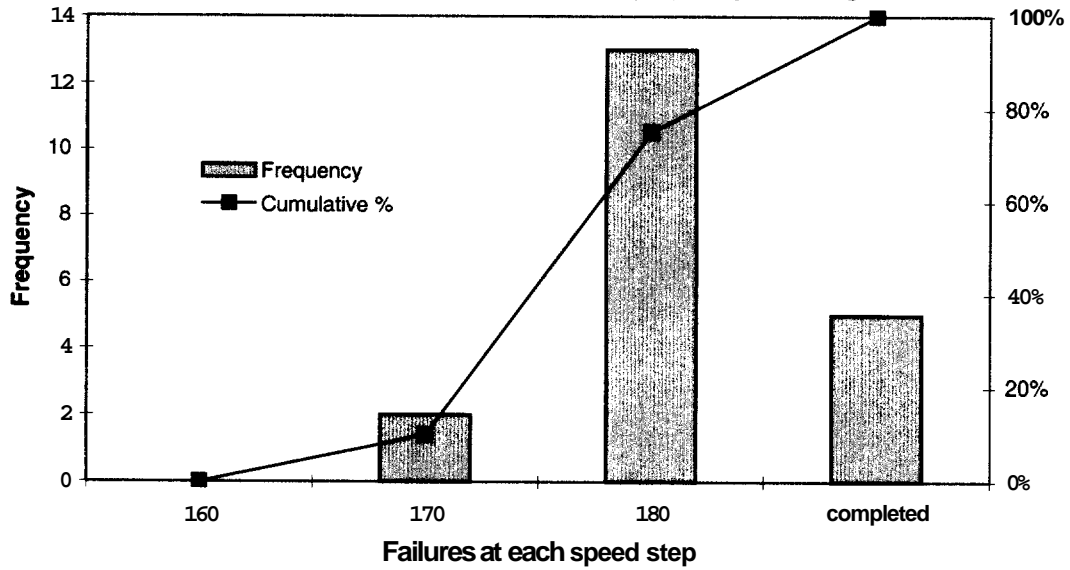
Figure 33: Number of failures at each speed step for a 'H' tire,  
data NHTSA  
[85% sidewall Load, 220 kPa (32psi), steps 20min]



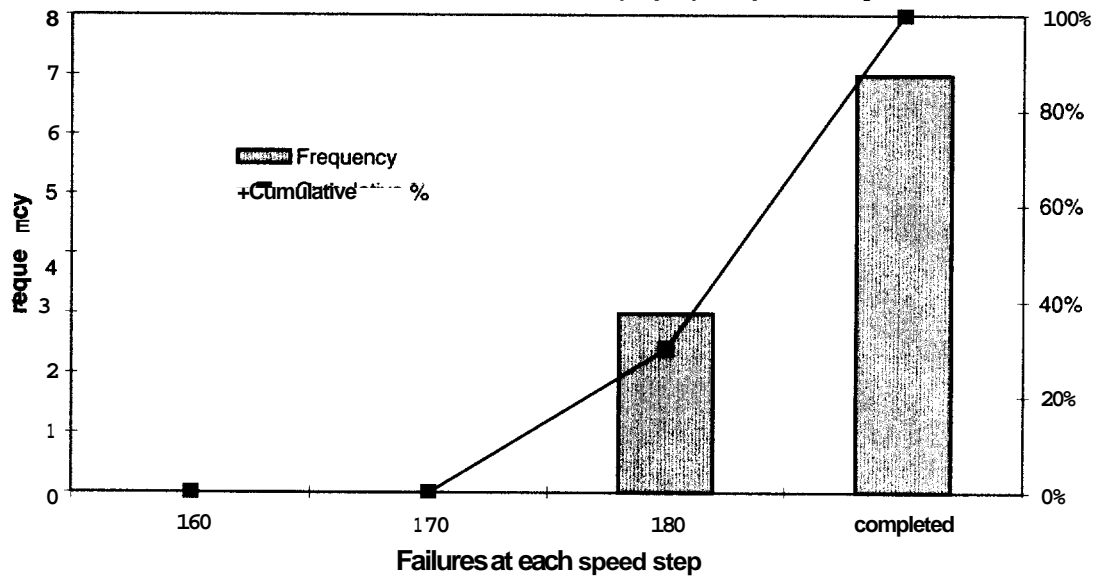
#### Tests at 210 kPa and 80% load (Subset B)

In this series of tests, tires were tested to either completion of a 30 minute segment at 160, 170, 180 km/h or tire failure, whichever came first. The distribution of time to failure for the tire that failed during the test is shown in Figures 34-36.

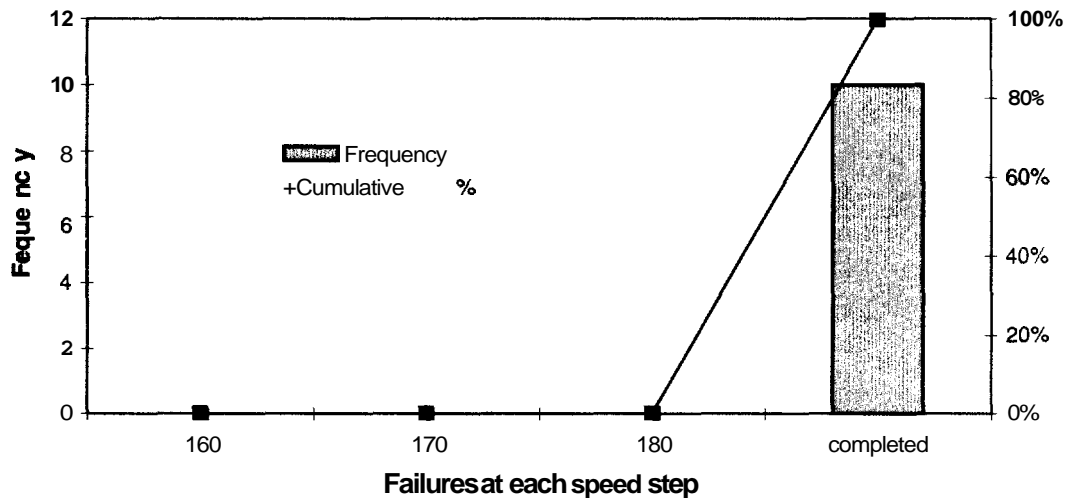
**Figure 34: Number of failures at each speed step for a 'S' tire,  
data NHTSA  
[80% sidewall Load, 210 kPa (31psi), steps 30min]**



**Figure 35: Number of failures at each speed step for a 'T' tire,  
data NHTSA  
[80% sidewall Load, 210 kPa (31psi), steps 30min]**



**Figure 36: Number of failures at each speed step for a 'H' tire,  
data NHTSA  
[80% sidewall Load, 210 kPa (31psi), steps 30min]**



### **Tests at 140 kPa and 70% of maximum load (Subset C)**

In this series of tests, all tires were tested to failure.

Figure 37 is a histogram of the speed-at-failure of 'S' type tires tested at 140 kPa (20 psi) pressure. The test conditions and speed profile were described earlier in Table 3 and Figure 2. The histogram illustrates the speed-at-failure for 20 tires described in category I of the NHTSA high-speed test section. At this test condition, each one of the tires failed at or before reaching the SR (180 km/h) for this tire type.

**Figure 37: Distribution of failures at each speed step for 'S' tires,  
Data NHTSA test condition  
[70% sidewall Load, 140 kPa (20 psi), 20 min at SR]**

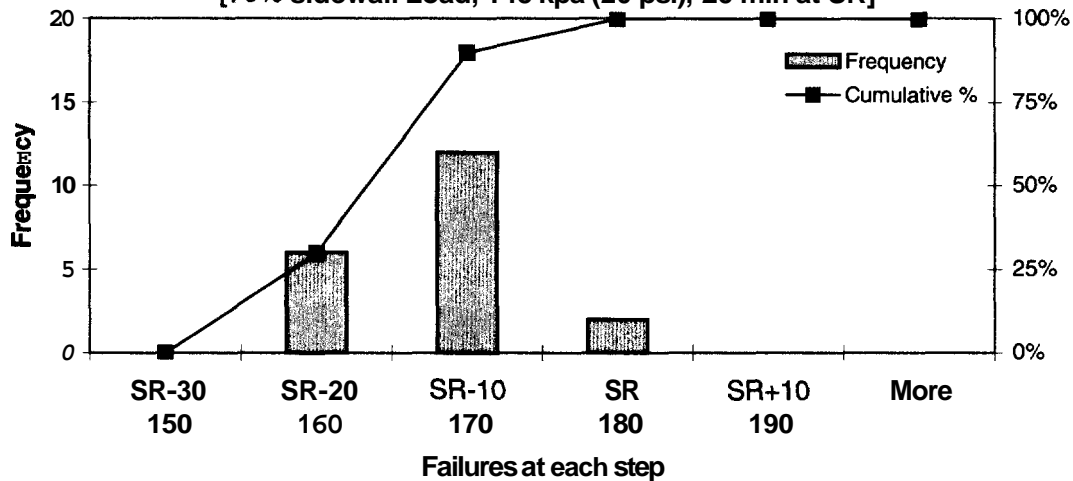


Figure 38 is a histogram of the speed-at-failure of 'T' type tires tested at 140kPa (20 psi) pressure. The test conditions and speed profile are described in Table 3 and Figure 2. The histogram illustrates the speed-at-failure for 10 tires described in category II of the NHTSA high-speed test section. At this test condition, 50 percent of the tires failed before completing the SR (190 km/h) step.

**Figure 38: Distribution of failures at each speed step, for 'T' tires,  
Data NHTSA; test condition  
[70% sidewall Load, 140 kPa (20 psi), 20 min at SR]**

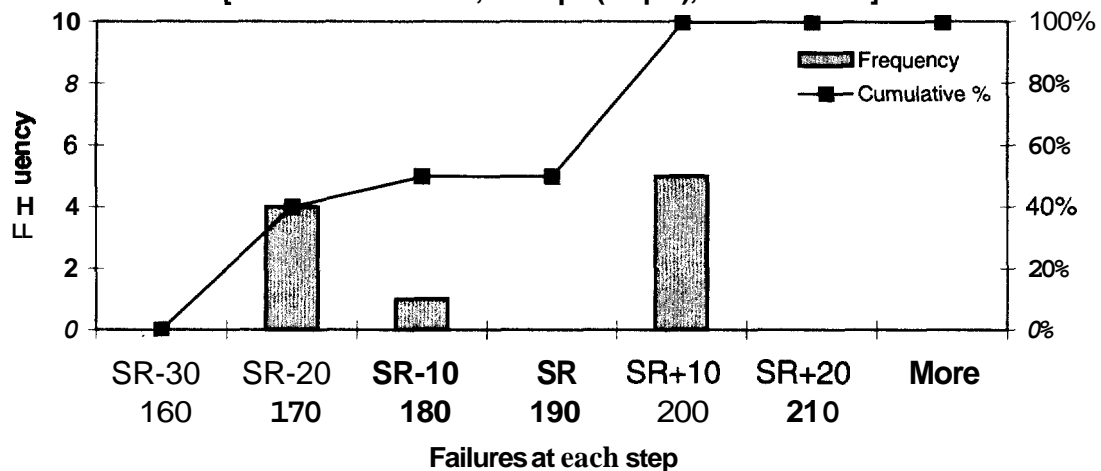
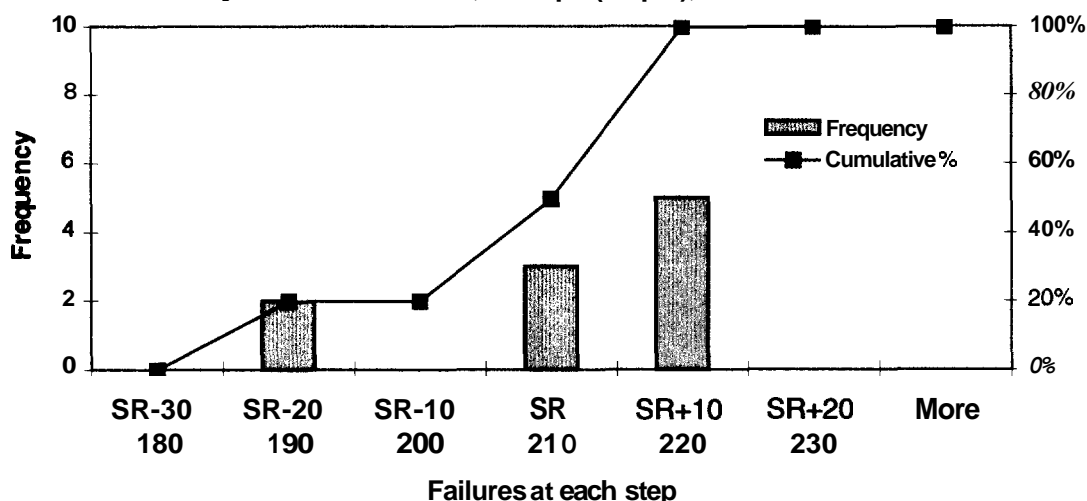


Figure 39 is a histogram of the speed-at-failure of 'S' type tires tested at 140kPa (20 psi) pressure. The test conditions and speed profile are described in Table 3 and Figure 2. The histogram illustrates the speed-at-failure for 10 tires described in category



III of NHTSA high-speed test section. At this test condition, 50 percent of the tires failed before completing the **SR (210 km/h)** step.

**Figure 39: Distribution of failures at each speed step, for 'H' tires,  
Data NHTSA; test condition  
[70% sidewall Load, 140 kPa (20 psi), 20 min at SR]**



### 4.3 Summary of Results

The mean speed-at-failure for **S**, **T**, and **H** type tires at **140 kPa (20 psi)**, **180 kPa (26 psi)**, **210 kPa (30.5 psi)**, **220 kPa (32 psi)**, **240 kPa (35 psi)**, and **300 kPa (44 psi)** are shown in Figures 40, 41, and 42 respectively. Bars of the mean speeds at **210 kPa** and **220 kPa** inflation pressures are colored or shaded as the tests were terminated once the SR was attained.

**Figure 40: Average Speed-at-failure versus Inflation Pressure  
'S' type tires, SR = 180 km/h**

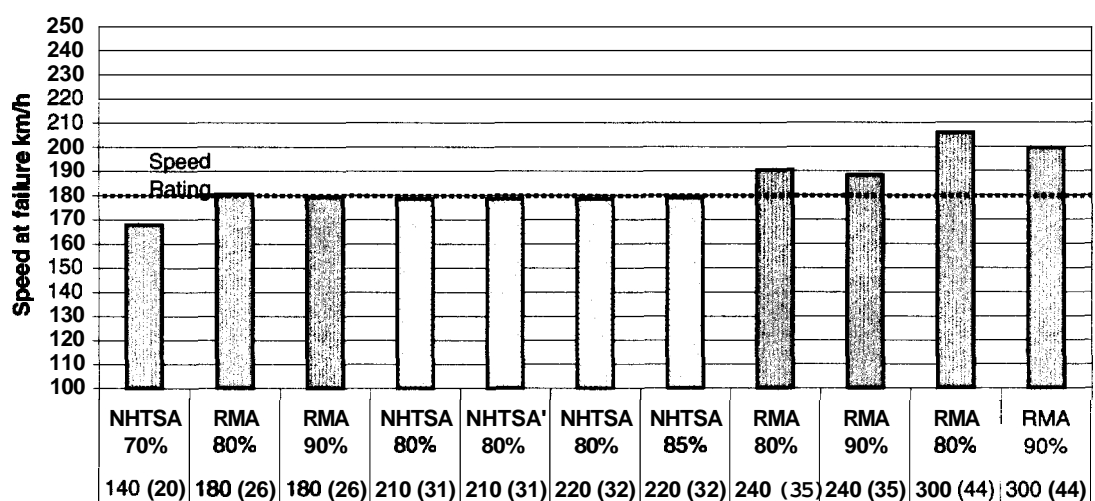


Figure 41 : Average Speed-at-failure versus Inflation Pressure  
'T' type tires, SR = 190km/h

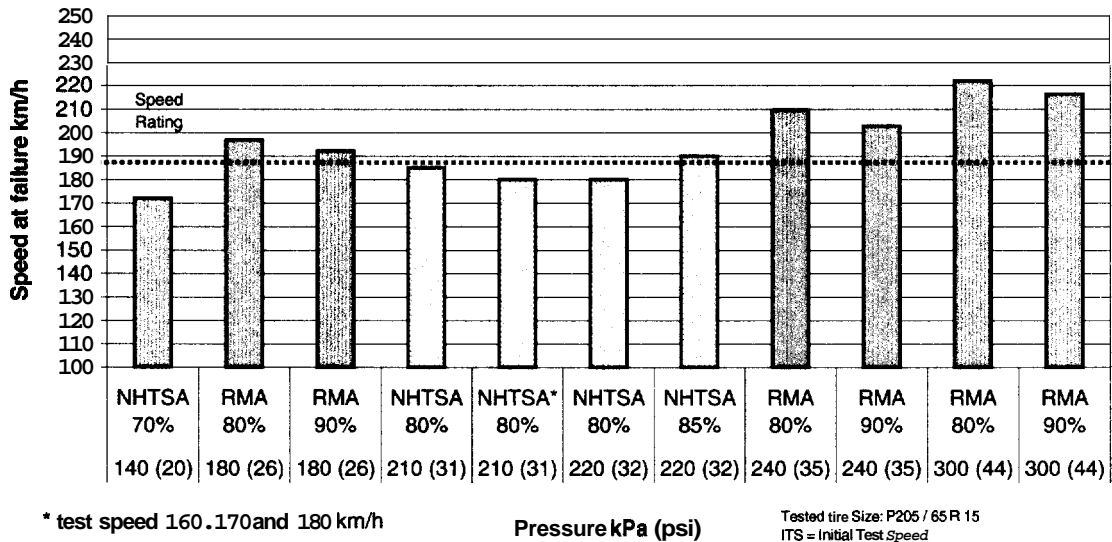
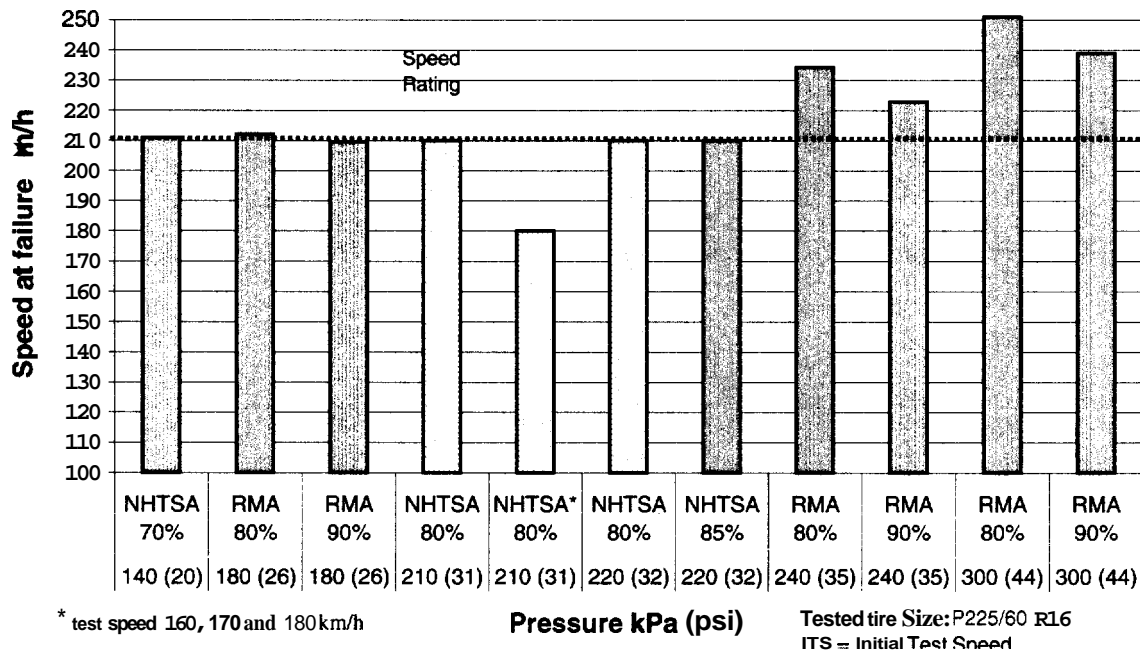


Figure 42: Average Speed-at-failure versus Inflation Pressure  
'H' type tires, SR = 210km/h



## 5 ANALYSIS AND CONCLUSIONS

### 5.1 Analysis

#### Effect of load on tire performance

A summary of the RMA test data was shown in Figures 22-24. This summary shows the effect of changing the load between 80 and 90 percent the of maximum load carrying capacity, as marked on the sidewall, of the tire. There is a small but consistent

reduction in the average speed-at-failure for the tests at 90 percent load when compared to the tests at 80 percent load. The size of this decrease is more pronounced at the higher test pressures than at the 26 psi test pressure. The size of the decrease is also more pronounced for tires with higher speed ratings. Tests for statistical significance of these differences are presented in Appendix 6.1.

**Conclusion:** There is a definite but small decrease in average speed-at-failure for tires tested at 90 percent of maximum sidewall load compared to tires tested at 80 percent of maximum sidewall load. The size of decrease varies from zero for 'S' tires at 26 psi to 14 km/h for 'H' tires at 44 psi.

### **Effect of test pressure on tire performance**

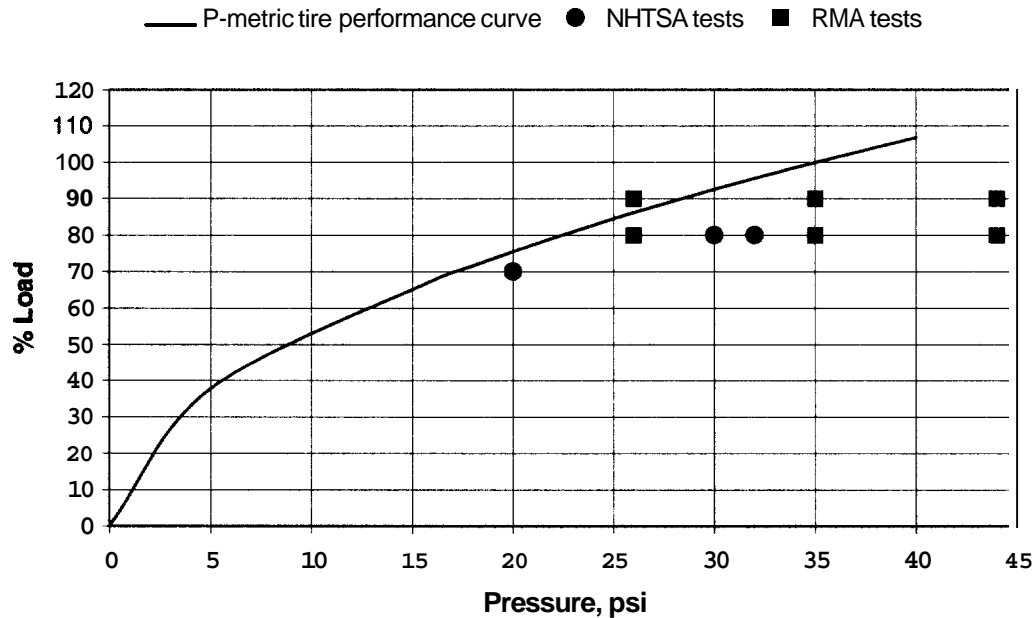
The RMA data (again Figures 22-24) also show the effect of variations in test pressure on the average speed at which tires fail. These figures clearly show that, under the load conditions of the tests, the average speed of failure is at, or above, the speed rating of the tire for each of the three test pressures used by RMA. The average speed-at-failure is 14.7 km/h above the speed rating at 35 psi and 29.0 km/h above the speed rating at 44 psi. However, as can be seen in Figures 4-21, a significant percentage of the tires failed at a speed lower than the SR at 26 psi. By contrast, no tire failed at a speed lower than the SR at 44 psi; and only 5 (out of **168**) failed at a speed lower than the SR at 35 psi.

**Conclusion:** Inflation pressure has a significant effect on the speed-at-failure. Inflation pressure of 26 psi produces a substantial number (32 out of 168, or 19 percent) of failures at speeds lower than the speed rating of the tire. Inflation pressure of 35 psi produces only a small number of failures below the speed rating of the tire.

### **Combined effect of load and pressure on tire performance**

The load formula for "P-metric" type tires given by the T&RA represents one perspective on the combined effect of these two variables. This relationship between sidewall load and pressure is shown graphically in Figure 43. One hypothesis associated with this curve is that the performance of a tire is the same for a test condition anywhere on the curve. Tire performance (in this case, tire speed-at-failure) should be the same if tested at 35 psi and 100 percent of sidewall load, or if tested at 20 psi and 75 percent of sidewall load, or at 26 psi and 86 percent of sidewall load, etc. In Figure 43, the RMA and the NHTSA test conditions are shown with respect to the load formula. The results of both the RMA and NHTSA tests were summarized in Figures 40-42. The RMA data in these figures show that the mean speed-at-failure is very close to the speed rating, and thus these data support the hypothesis that the performance is the same for pressures of 26 psi and 35 psi. (Note that it is necessary to reduce the failure speed at 35 psi by the incremental amounts from Figures 22-24 noted above to estimate failure speed at a condition of 100 percent load and 35 psi.) The NHTSA data also support the hypothesis for tires with "H" speed rating at 20 psi and 70 percent load. However, at the 20 psi / 70 percent load condition the NHTSA data show an average failure speed between 10 and 15 km/h below the speed rating for tires with speed ratings of S and T.

**Figure 43: Tire Performance Curve**



**Conclusion:** The effect of contributions of load and pressure is conveniently described by the T&RA tire performance curve for inflation pressures of **26** psi and higher. The effect is that the mean speed-at-failure for any test point on the curve is approximately equal to the speed rating of the tire. The data suggests that, for inflation pressure less than **26** psi and for tires with speed ratings of “T” or less, the mean speed-at-failure is 10– 15 km/h less than their speed rating.

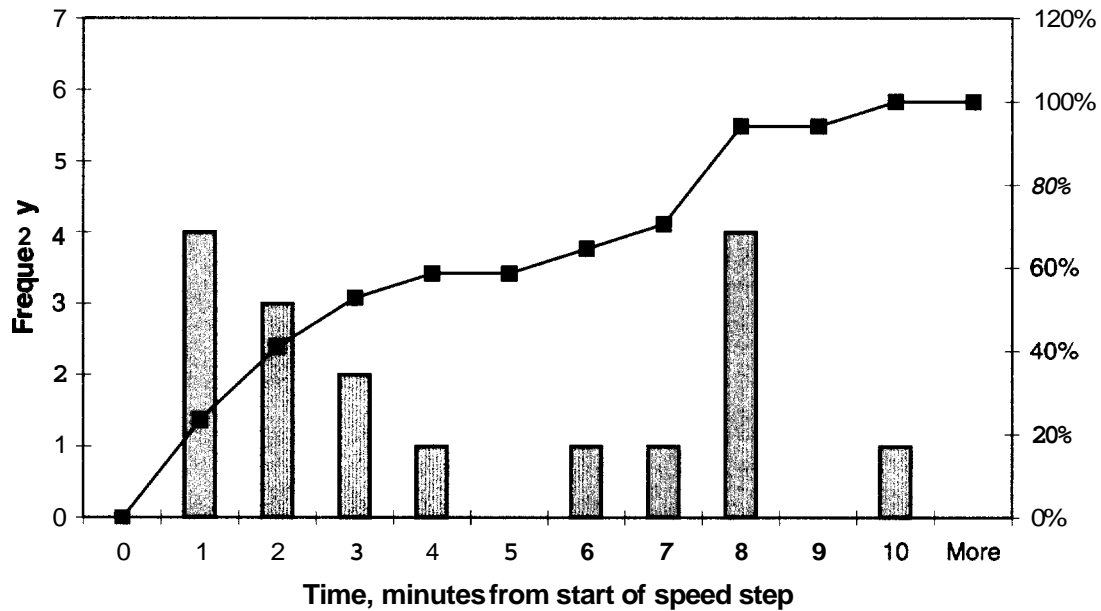
### Effect of length of time at a speed on tire performance

One question that occurs frequently is whether the length of time at a speed makes a difference in the likelihood of failure at that speed. To address this question, a subset of RMA data consisting of the tires that failed at the speed rating of the tire was selected. This subset of data can be further subdivided by the two types of tests run by RMA. The “ITS=SR-40” used a 10 minute duration for all speed steps. The “ITS=SR-20” tests used a 10 minute duration for each speed step except the speed rating. The duration at the SR was 30 minutes. The results for this subset are summarized in Table 5 and the distribution of time within the speed step to failure for tires in each of these subsets is shown in Figures 44-57. In the “ITS=SR-40” subset, i.e., 10 minutes at the rated speed, there is some variation in the shape of the distributions, but in general they approximate a **uniform distribution** over the 10 minutes. However, the distributions for the “ITS=SR-20” subsets, i.e., 30 minutes at rated speed, show a different pattern. For the tests at **26** psi, the distributions are heavily weighted toward the short time end; i.e., substantially more than 50 percent of the tires in each speed-rating group fail within the first 10 minutes. For the tests at 35 psi however, the distributions are heavily weighted toward longer times; i.e., substantially more than 50 percent of the tires in each speed-rating group fail after the first 10 minutes.

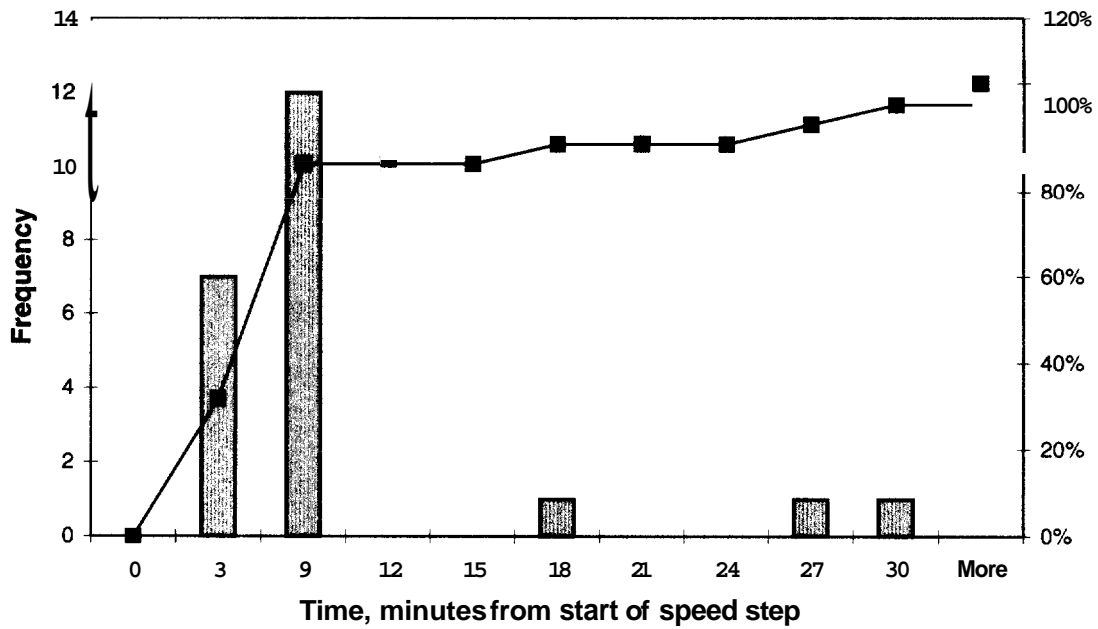
Conclusion: For high-speed tests of tires at maximum sidewall pressure (35 psi for the tires tested) it is necessary to test with durations greater than 10 minutes to fully judge failure rates.

Pressure kPa (psi)	Speed Rating					
	'S'		'T'		'H'	
	10min @SR	30min @SR	10min @SR	30min @SR	10min @SR	30min @SR
180 (26)	17	22	14	16	7	13
240 (35)	3	16	2	8	2	4
300	0	0	0	0	2	2

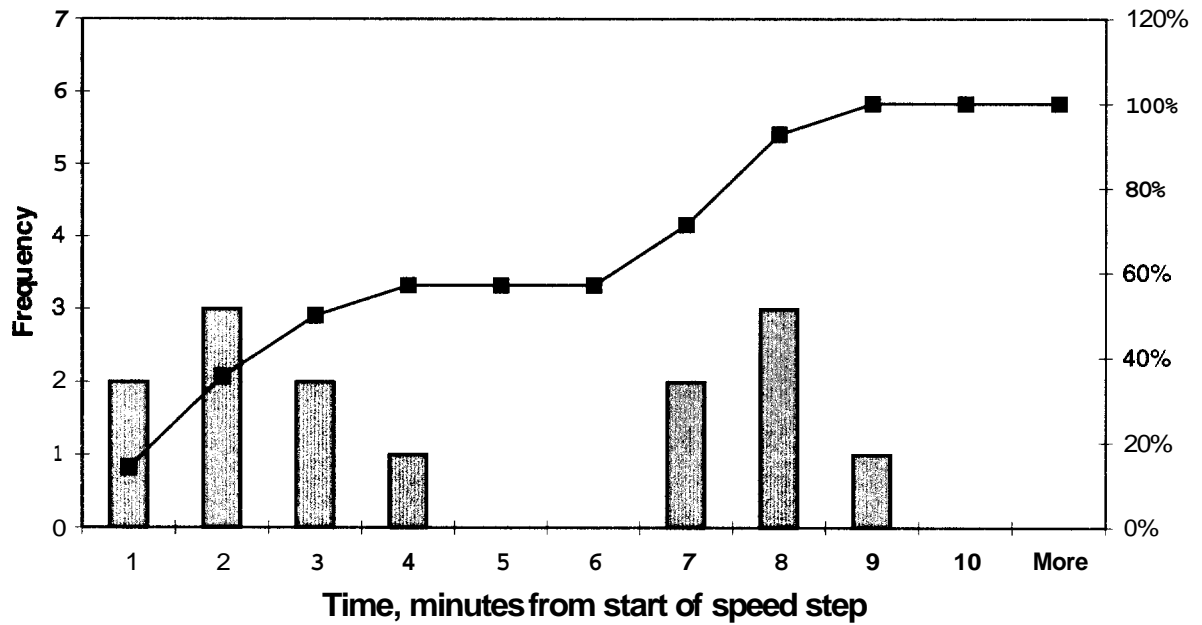
**Figure 44: Distribution of failure at speed step 180km/h for an 'S' tire,  
Data RMA, [80 & 90% sidewall Load, 180 kpa (26 psi), 10 min at SR]**



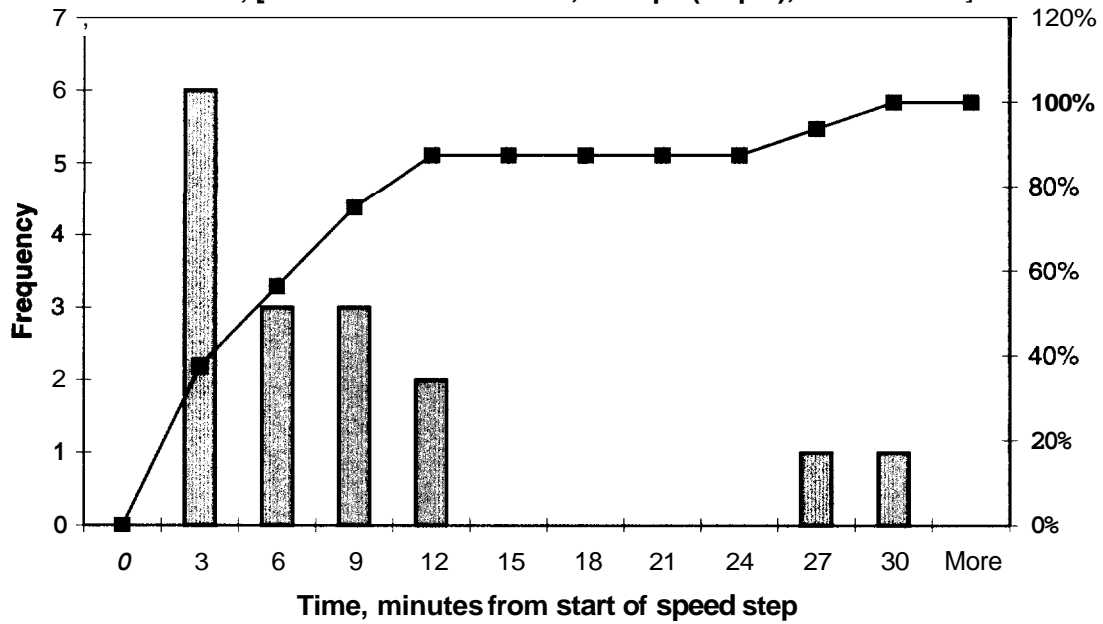
**Figure 45: Distribution of failures at speed step 180km/h for a 'S' tire, Data RMA; [80 & 90% sidewall Load, 180 kpa (26 psi), 30 min at SR]**



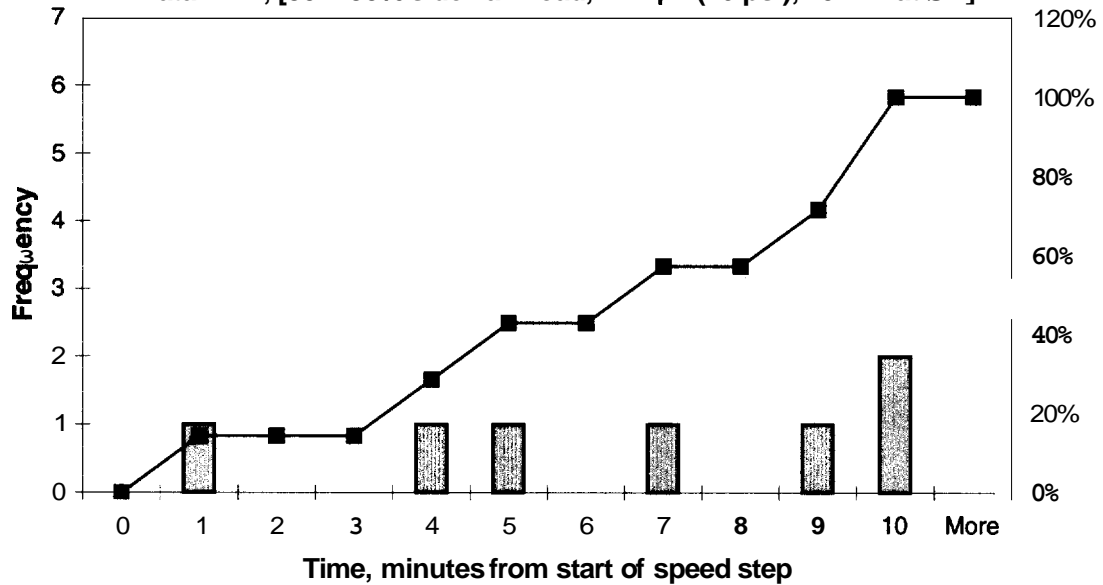
**Figure 46: Distribution of failures at speed step 190km/h for a 'T' tire, Data RMA [80 & 90% sidewall Load, 180 kpa (26 psi), 10 min at SR]**



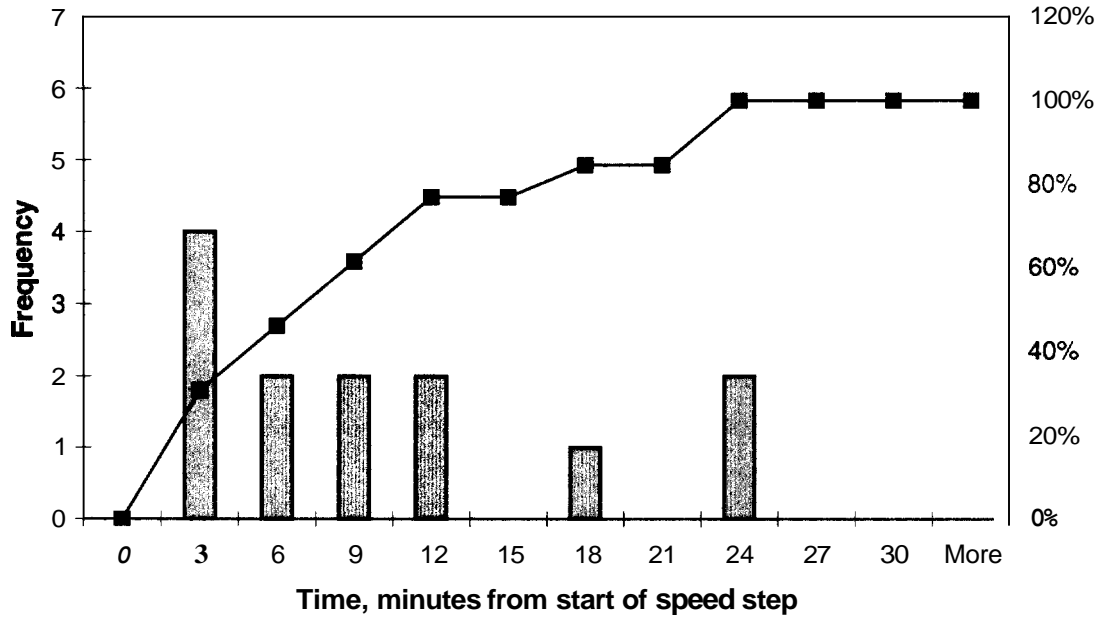
**Figure 47: Distribution of failures at speed step 190km/h for a 'T' tire,  
Data RMA; [80 & 90% sidewall Load, 180 kpa (26 psi), 30 min at SR]**



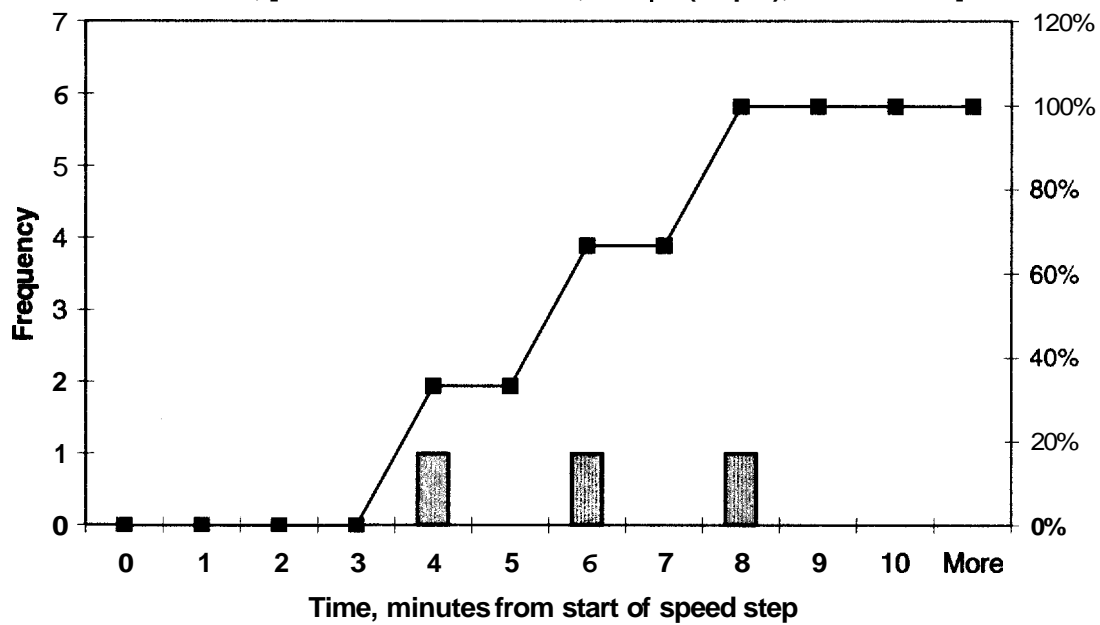
**Figure 48: Distribution of failures at speed step 210km/h for an 'H' tire;  
Data RMA, [80 & 90% sidewall Load, 180kpa (26 psi), 10 min at SR]**



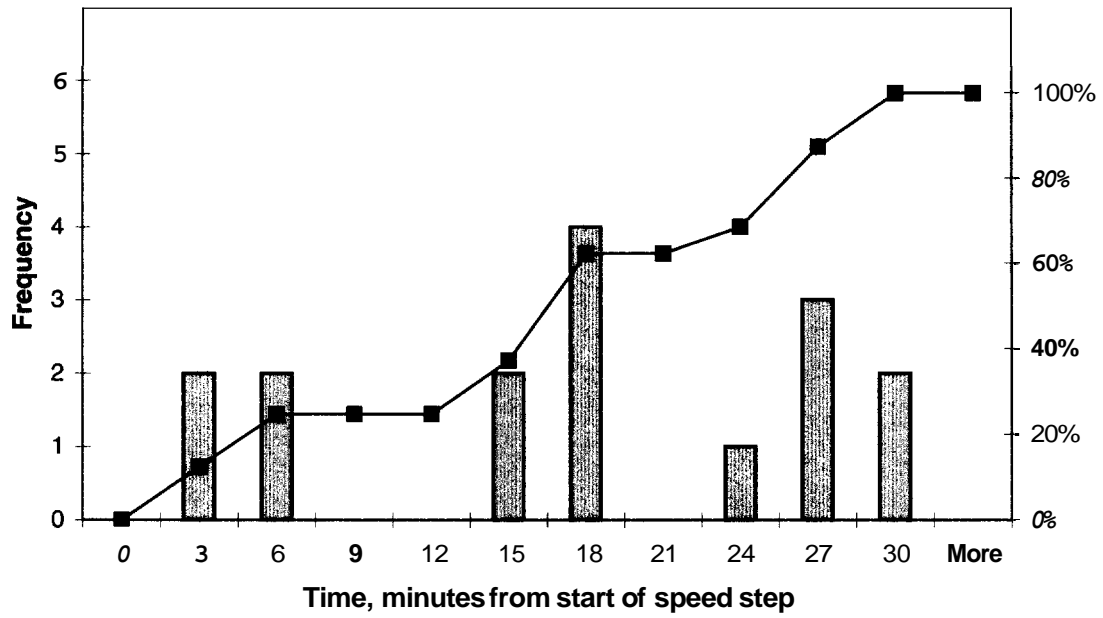
**Figure 49: Distribution of failures at speed step 210km/h for a 'H' tire,  
Data RMA; [80 & 90% sidewall Load, 180 kpa (26 psi), 30 min at SR]**



**Figure 50: Distribution of failure at speed step 180 km/h for an 'S' tire;  
Data RMA, [80 & 90% sidewall Load, 240kpa (35 psi), 10 min at SR]**







**Figure 52: Distribution of failure at speed step 190 km/h for a 'T' tire;  
Data RMA, [80 & 90% sidewall Load, 240 kpa (35 psi), 10 min at SR]**

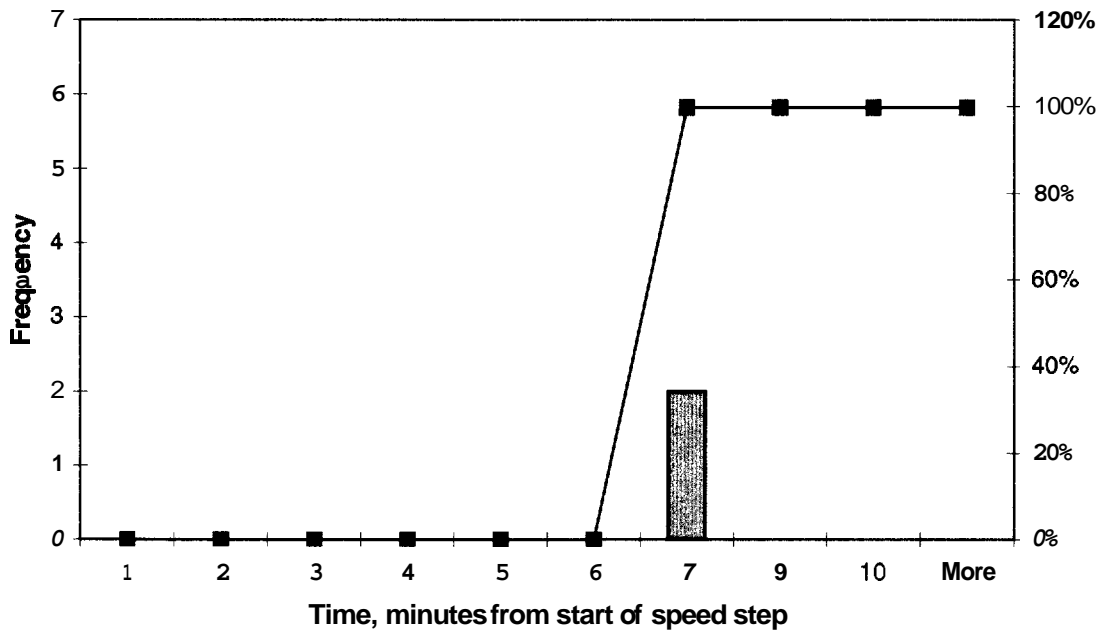


Figure 53: Distribution of failures at speed step **190km/h** for a 'T' tire,  
Data RMA, [80 & 90% sidewall Load, 240 kpa (35 psi), 30 min at SR]

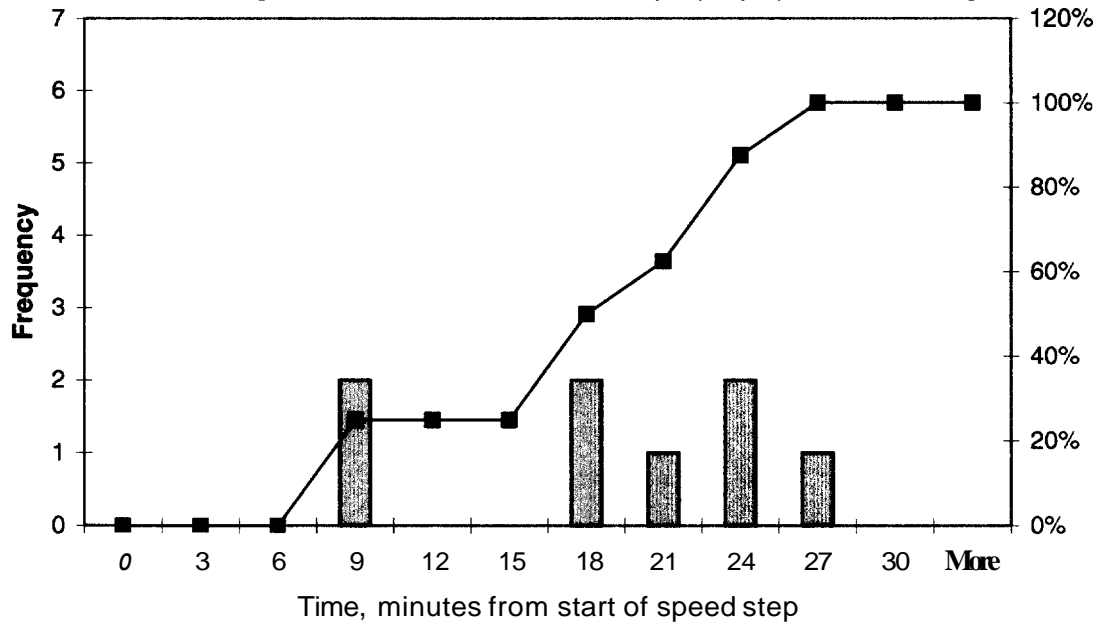
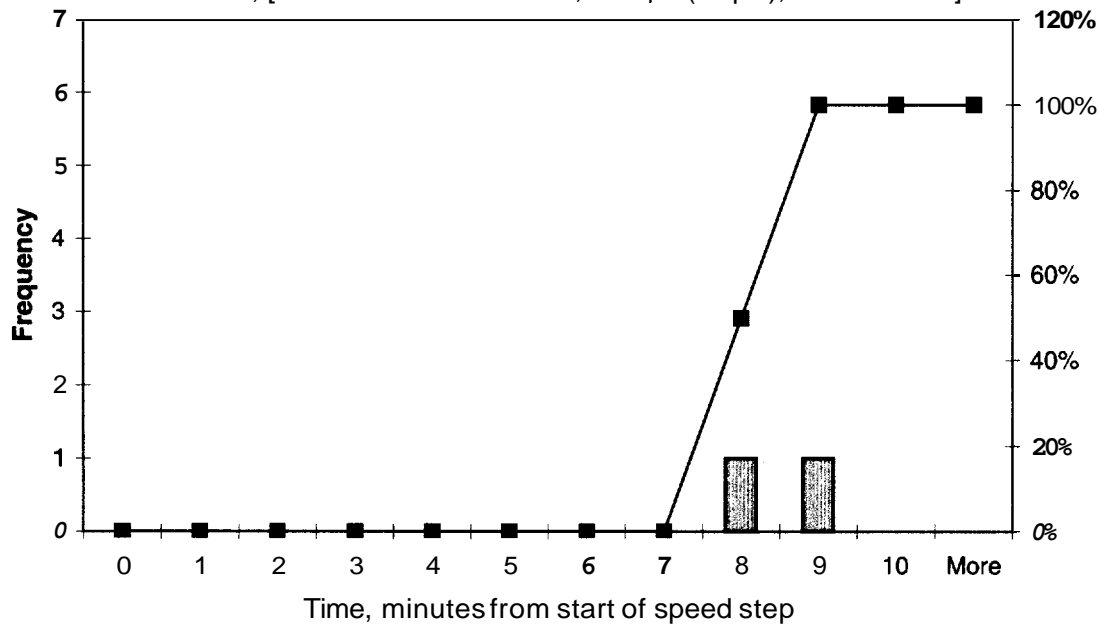
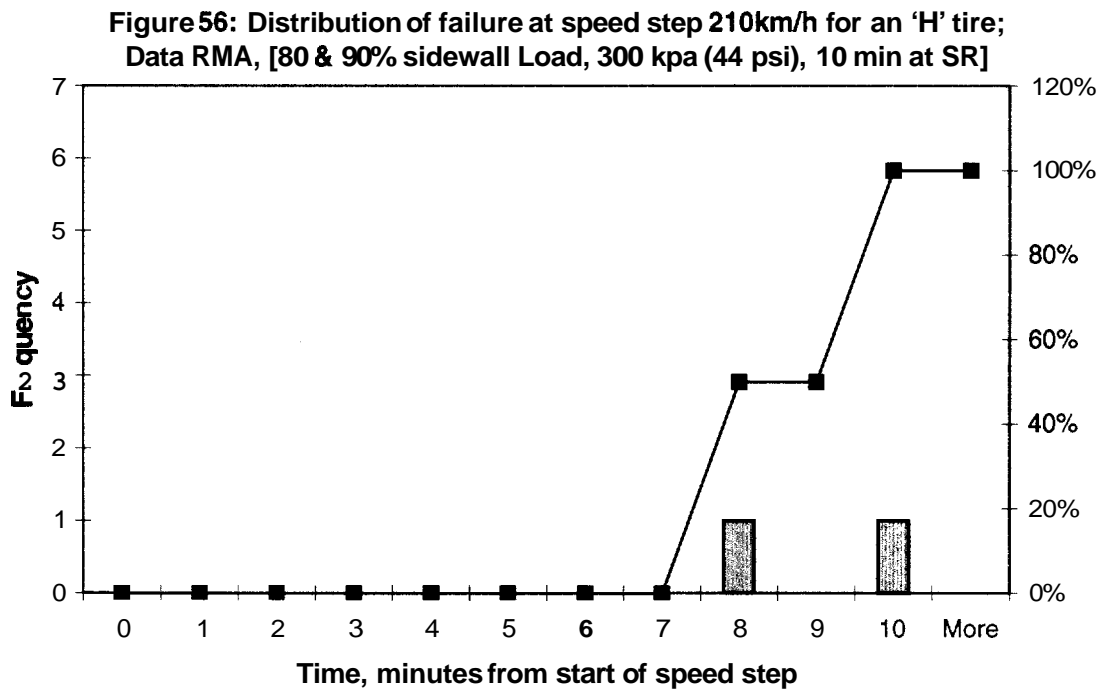
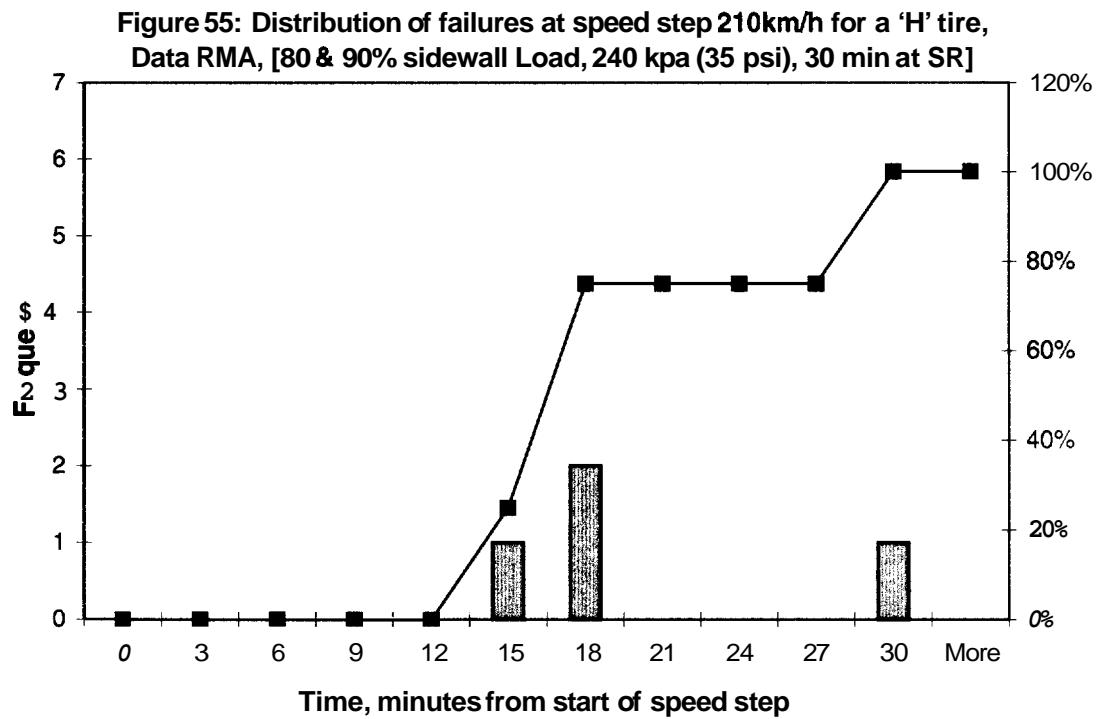
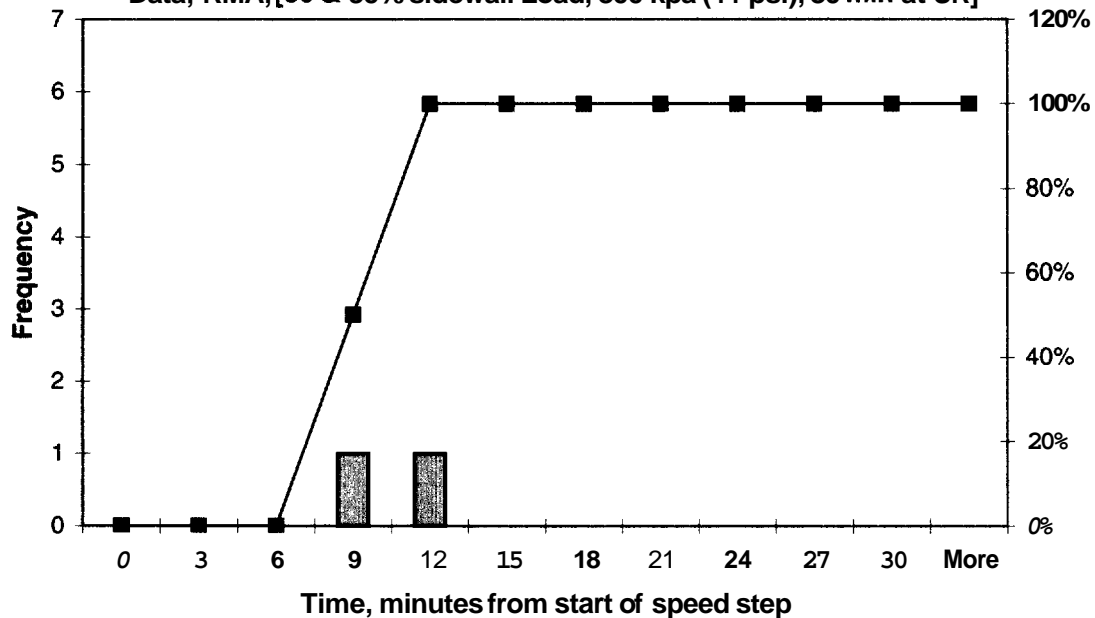


Figure 54: Distribution of failure at speed step **210km/h** for a 'H' tire;  
Data RMA, [80 & 90% sidewall Load, 240kpa (35 psi), 10 min at SR]





**Figure 57: Distribution of failure at speed step 210km/h for an 'H' tire  
Data; RMA, [80 & 90% sidewall Load, 300 kpa (44 psi), 30 min at SR]**



## 5.2 Summary of Conclusions

### Effect of load on tire performance

There is a small, but definite, decrease in the average speed-at-failure for tires tested at **90** percent of maximum sidewall load compared to tires tested at 80 percent of maximum sidewall load.

### Effect of test pressure on tire performance

Inflation pressure has a significant effect on speed-at-failure. Inflation pressure of 26 psi produces a substantial number (32 out of 168, or 19 percent) of failures at speeds less than the speed rating of the tire. While only 5 out of 168 (3 percent) fail below the rated speed at 35 psi.

### Combined effect of load and pressure on tire performance

The combination of NHTSA and RMA data support the hypothesis that the performance of a tire is the same for a test condition on the T&RA load curve with an inflation pressure of 26 psi or more. At lower pressures, specifically at 20 psi, failure rates are higher than would be predicted from the T&RA curve.

### Effect of length of time at a speed on tire performance

For high-speed tests at the maximum sidewall pressure, (35 psi for the tires tested) it is necessary to test with durations greater than 10 minutes to fully judge failure rates.

**How would the tires tested in these programs perform in the proposed high-speed test and the high-speed, low-pressure test (“Alternative 2”)?**

The proposed high-speed test is run at 32 psi and 85 percent of sidewall load. The high-speed, low-pressure test (“Alternative 2”) is run at 20 psi and 67 percent of sidewall load. The duration at each speed would be 30 minutes. Both of these points are slightly below the T&RA curve. The test would start at a speed of 140km/h and would increase in 10km/h increments until it reaches a speed of 160km/h or the tire fails. The tire is considered to have passed if it completes 30 minutes at 160km/h. An estimate of the number that would pass, based on the tests discussed in the study, is given below:

**32 psi test** (based on RMA data)

S-rated tires (Figures 3, 4, 9, & 10): 100percent would have passed.

T-rated tires (Figures 5, 6, 11, & 12): 100percent would have passed.

H-rated tires (Figures 7, 8, 13, & 14): 100percent would have passed.

**20 psi test** (based on NHTSA data)

S-rated tires (Figure 24): 70.0 percent would have passed.

T-rated tires (Figure 25): 100percent would have passed.

H-rated tires (Figure 26): 100percent would have passed.

An extrapolation of these results for tires with speed ratings of Q, and R tires is shown in Appendix 6.3. That analysis suggests that:

**32 psi test** (based on RMA data)

Q-rated tires: 63.7 percent would have passed.

R-rated tires: 90.7 percent would have passed.

S-rated tires: 100percent would have passed.

**32 psi test** (based on NHTSA data)

Q-rated tires: 43.0 percent would have passed.

R-rated tires: 90.0 percent would have passed.

S-rated tires: 98.0 percent would have passed.

**20 psi test** (based on NHTSA data)

Q-rated tires: 25.0 percent would have passed.

R-rated tires: 37.5 percent would have passed.

S-rated tires: 70.0 percent would have passed.

## 6 APPENDICES

### 6.1 Hypothesis Test for F Statistic (see Section 5.1)

Null hypothesis	$H_0 : \beta_1 = 0$ dependent variable is independent There is no linear relationship between speed-at-failure and pressure, speed-at-failure and test condition. speed-at-failure and tire type
Alternative hypothesis	$H_1 : \beta_1 \neq 0$ there is a linear relationship between speed-at-failure and pressure, speed-at-failure and test condition. speed-at-failure and tire type

Test statistic

If  $F^* \leq F(1-\alpha; 1, n-2)$ , conclude  $H_0$

If  $F^* > F(1-\alpha; 1, n-2)$ , conclude  $H_1$

Where  $F^* = \frac{MSR}{MSE}$

$F(1-\alpha; 1, n-2)$  is the (1-a) 100 percentile of the approximation of F distribution.  
 A 95 percent confidence interval is used.

Variable	$F^*$ value		F value
Tire type (S, T, or H)	457.90	>	3.84
Pressure (180, 240, or 300)	239.76	>	3.84
Test Condition (ITS-40, or ITS-20)	3.36	<	3.84

The alternative hypothesis is true for the tire type and pressure i.e. there is a linear relationship between tire type and inflation pressure with speed at which the tire fails.

The null hypothesis is true for the test condition i.e. selection of test condition does not influence the speed at which the tire fails.

## 6.2 Tire Performance Curve

Load formula for **30**, **35**, **40**, and **45** series P-metric tires as per T&RA:

$$\text{Load } L = K \times \sqrt{P} \times S_d^{1.39} \times (Dr + S) \quad [1]$$

$L$  = Max Load (kg) round up from the mid point to nearest load index value

$$\begin{aligned} K &= 5.00 \times 10^{-5} \text{ (30 and 35 Series)} \\ &= 5.67 \times 10^{-5} \text{ (40 and 45 Series)} \end{aligned}$$

$P$  = Inflation Pressure (kPa)

$$\begin{aligned} S_d &= \text{Reduced tire equivalent tire section width (mm)} \\ &= [0.3484 + 0.6497(A)] \times S_{0.85} \end{aligned}$$

$d$  = Design section height of round tire ( $0.96 S_{0.85}$ ) minus maximum section height of tire having depressed Crown (mm).

$$= 0.96 \times S_{0.85} - [1.02 \times (A \times S_{0.85})]$$

$$A = \text{Aspect Ratio} = \frac{H}{S_{0.85}}$$

The maximum load is given by load at maximum pressure specified on the sidewall of the tire, which is 35 psi for most of the P-metric tires. The maximum load can also be found by looking at the load index on the sidewall of the tire.

The relationship between the pressure and percentage load is determined by the ratio:

$$\text{Percent load: } \%L = \sqrt{\frac{P}{35}} \times 100$$

Where  $P$  is the pressure in psi at which the percent load is determined. The curve between percent load and pressure is shown in Figure 43. The high-speed tests conducted by RMA were at 180 kPa (26 psi), **240** kPa (**35** psi), and **300** kPa (44 psi) inflation pressure. The dark squares indicate the specification of the high-speed performance laboratory tests conducted by RMA. NHTSA conducted high-speed tests at **140** kPa (20 psi), 210 kPa (**30** psi), and **220** kPa (**32** psi); the dark circles indicate these tests.

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<sup>1</sup> Engineering Design Information, *The Tire and Rim Association, INC., 2001*

### **6.3 Estimation of High-speed Test Failure Rates**

This analysis was carried out for tire with Q, R, and S speed ratings.

#### **Failure rates for tests at 32 psi**

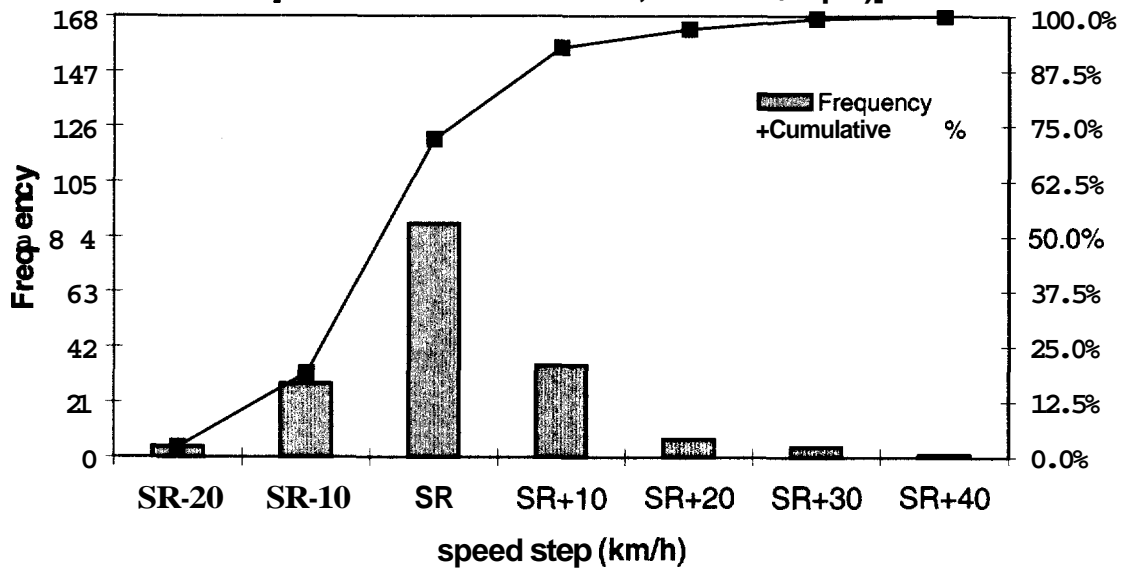
The underlying premise of this analysis is that for similar test conditions the distributions of failure speed relative to the tire's speed rating is the same for all the speed ratings. This hypothesis is not tested in this analysis, but Figures 4-39 suggest that it is a good approximation.

The RMA conducted high-speed tests at 26 psi (180 kPa) and 35 psi (240 kPa) at two test speed profiles described in Table 1 and Table 2, and at loads 80 and 90 percent SW load. In order to determine the distribution of speed-at-failure for tires tested at 32 psi the following steps were taken:

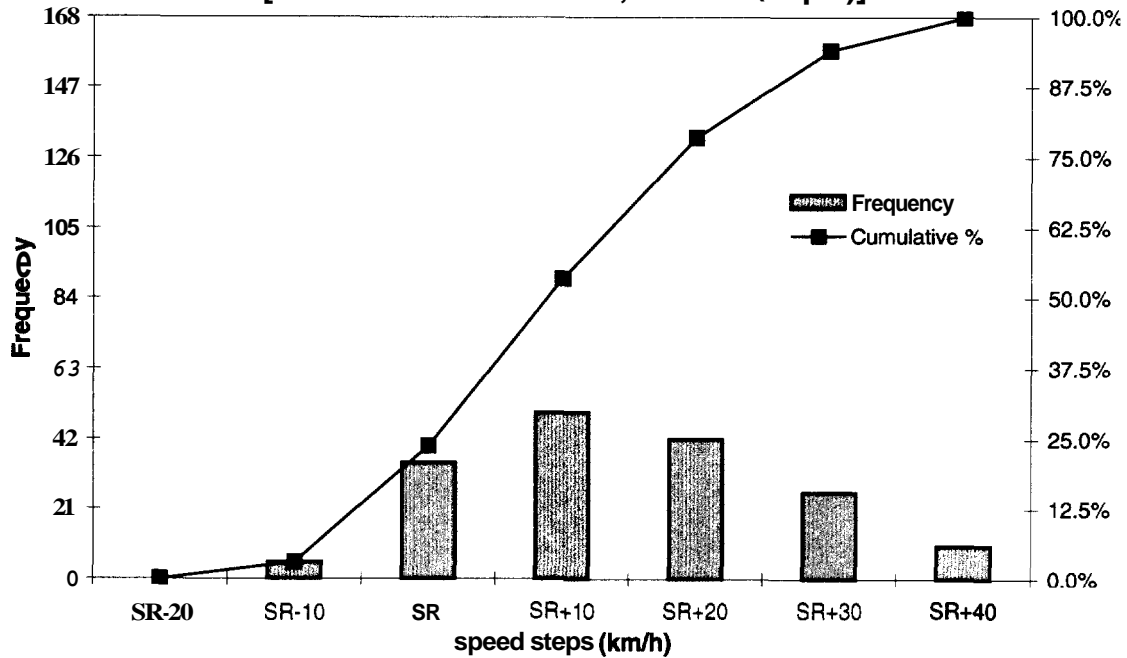
1. Combine results for tests at 26 psi and 35 psi into distributions of failure-speeds relative to speed at each of the two pressures. These are shown in Figure A.3.1 and Figure A.3.2.
2. Apply these distributions to tires with speed ratings of Q and R. This step is also applied to tires with speed rating of S as a check on variability. The results are shown in Figures A.3.3 – A.3.8.
3. From these figures, determine the percentage of tires that would not survive to the end of the 160km/h speed step for each of the two test pressures. These results are shown in the Table A.3.1.
4. Combine results for the two pressures into a weighted average corresponding to the test at 32 psi. These results are shown in the Table A.3.2.



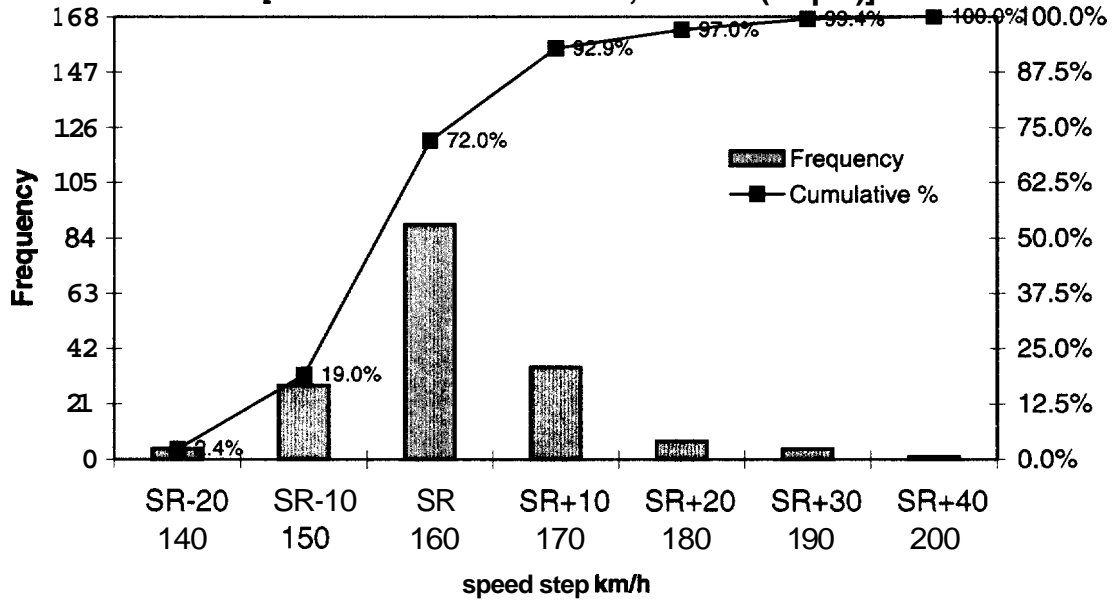
**Figure A.3.1: Estimated distribution of failures with respect to rated speed, RMA data  
[80 and 90% sidewall load, 180 kPa (26 psi)]**



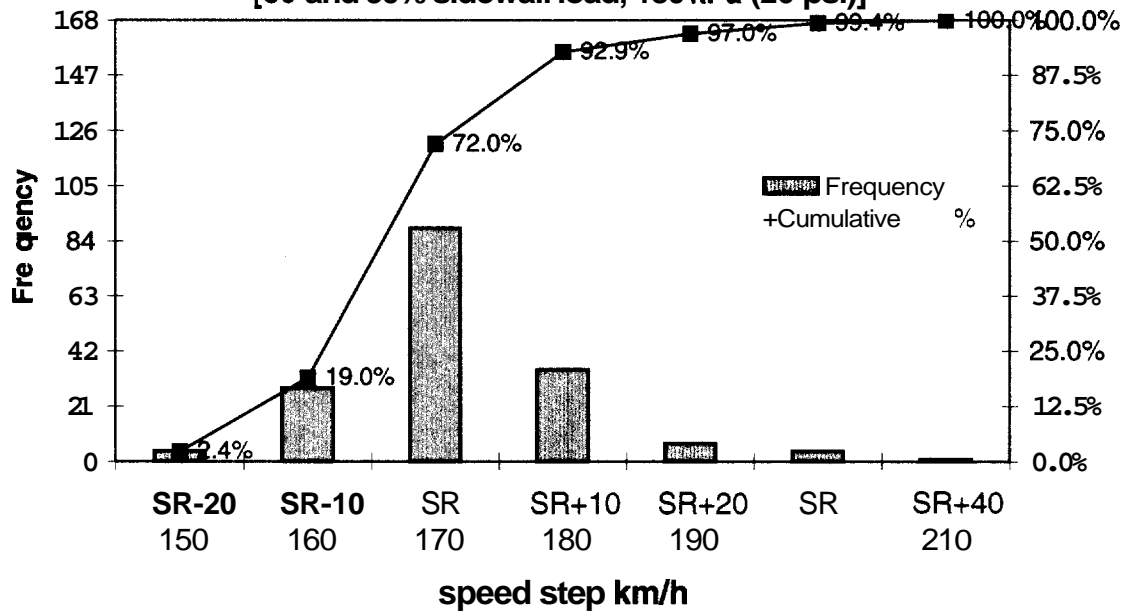
**Figure A.3.2: Distribution of failures with respect to rated speed, RMA data  
[80 and 90% sidewall load, 240 kPa (35 psi)]**



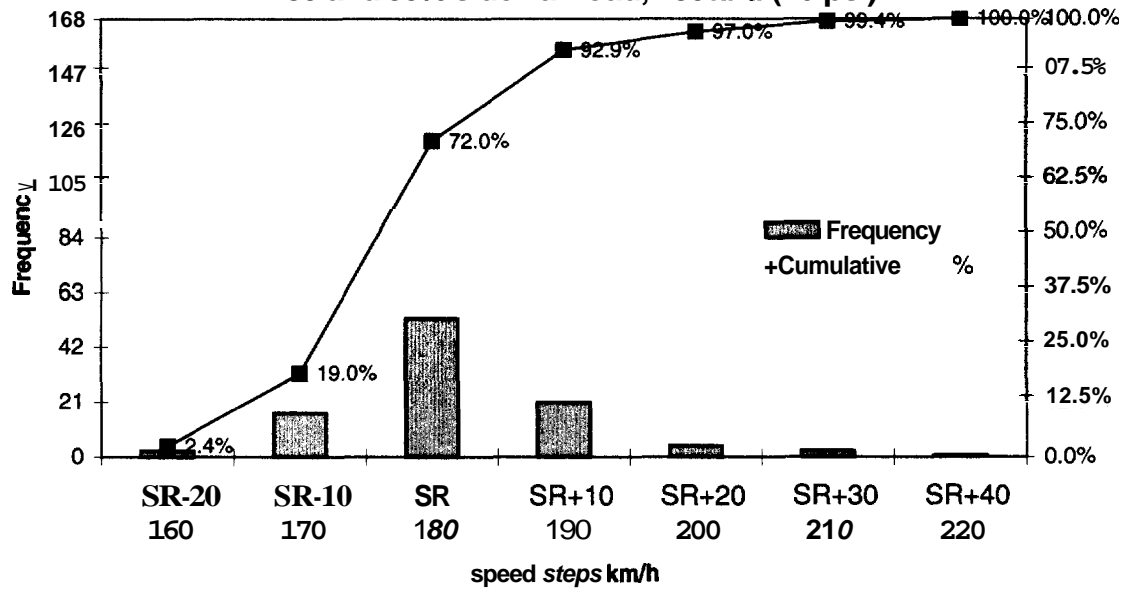
**Figure A.3.3: Estimated distribution of failures with respect to Rated Speed for Q tires (SR =160 km/h), RMA data [80 and 90% sidewall load, 180 kPa (26 psi)]**



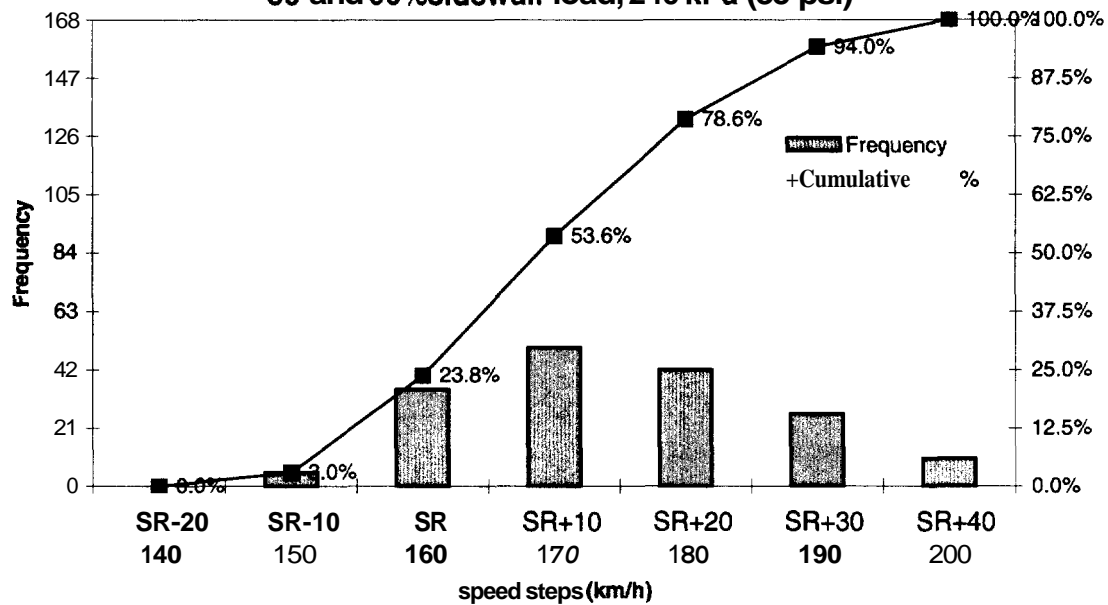
**Figure A.3.4: Estimated distribution of failures with respect to Rated Speed for R tires (SR =170 km/h), RMA Data [80 and 90% sidewall load, 180 kPa (26 psi)]**



**Figure A.3.5: Estimated distribution of failures with respect to Rated Speed for S tires(SR =180 km/h), RMA Data, 80 and 90% sidewall load, 180 kPa (26 psi)**



**Figure A.3.6: Estimated distribution of failures with respect to Q rated tires(160 km/h), RMA Data, 80 and 90%sidewall load, 240 kPa (35 psi)**



**Figure A.3.7: Estimated distribution of failures with respect to rated speed for 'R' tires (170 km/h), 80 and 90%sidewall load, 240 kPa (35 psi)**

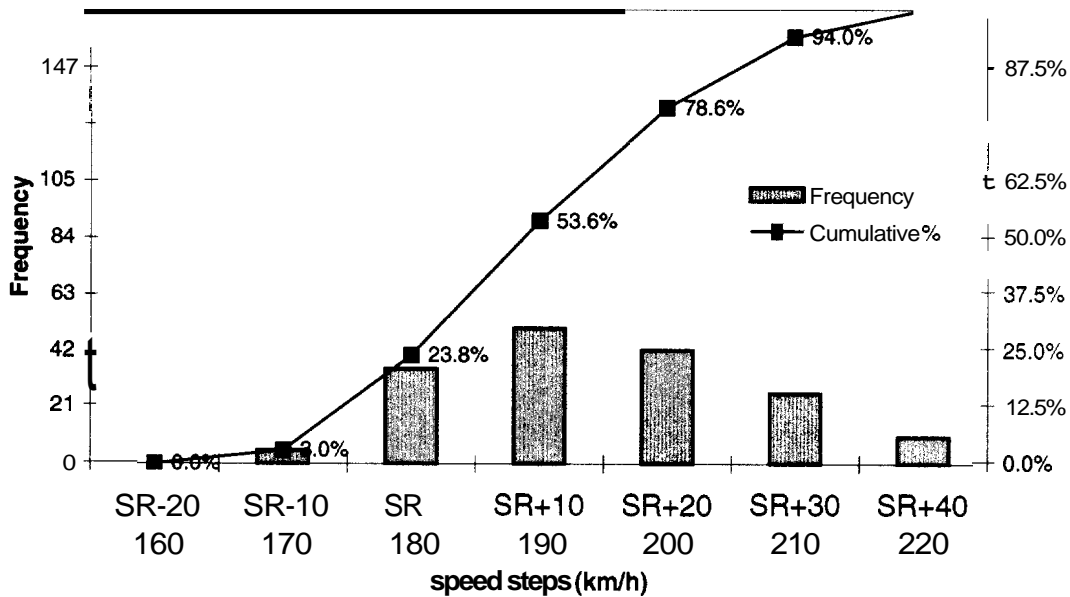
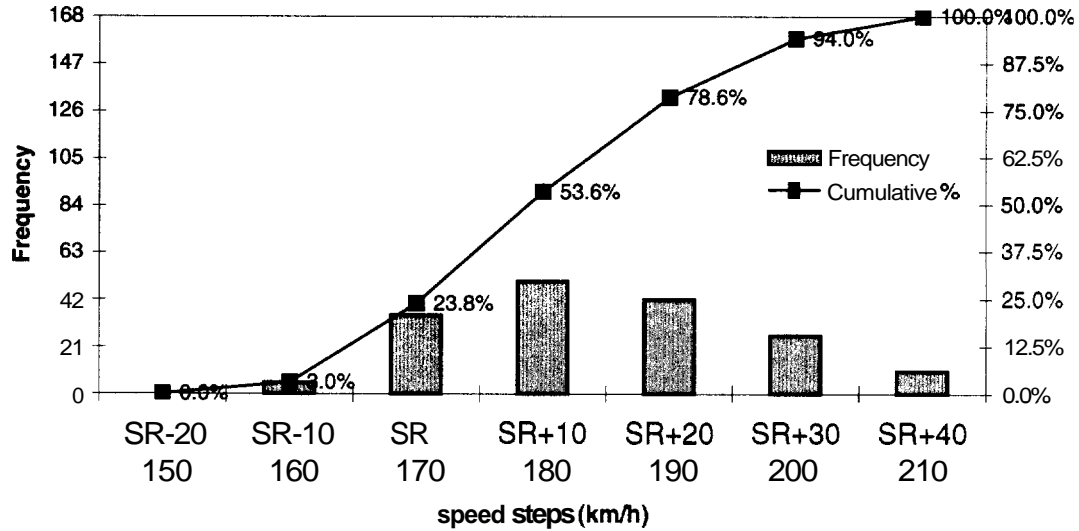


Table A.3.1: Percentage of tires that would not survive the proposed NPRM speed of 160km/h

Inflation Pressure	'Q' (160 km/h)	Speed Rating 'R' (170 km/h)	'S' (180km/h)
240 kPa	24	3	0
180kPa	72	19	2.4

Inflation Pressure	'Q' (160 km/h)	Speed Rating 'R' (170 km/h)	'S' (180km/h)
220 kPa	40	10.6	1.6

Failure rates for tests at **20 psi** (NHTSA data)

A similar process was followed for tests at 20 psi using the **NHTSA** test data

Figure A.3.9 illustrates the resulting estimated distribution of speed-at-failure for Q rated tires at 20 psi inflation pressure. The figure shows that about 75 percent of the Q rated tires fail to complete the proposed speed criteria of 160km/h.

Figure A.3.9: Estimated distribution of failures with respect to Rated speed for 'Q' tires (SR = 160 km/h)  
[70% sidewall load, 140 kpa (20 psi), 20 min step]

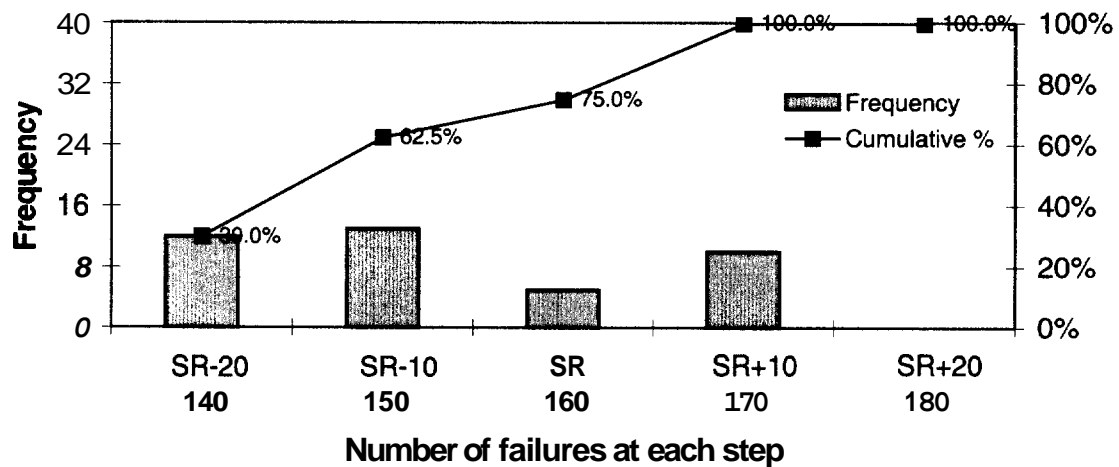


Figure A.3.10 illustrates the distribution of speed-at-failure for 'R' rated tires at 20 psi inflation pressure. The figure shows that about 63 percent of the 'R' rated tires fail to complete the proposed speed criteria of 160km/h.

Figure A.3.10: Estimated distribution of failures with respect to 'R' rated tires (SR =170 km/h), 70% sidewall load, 140 kpa (20 psi), 20 min step

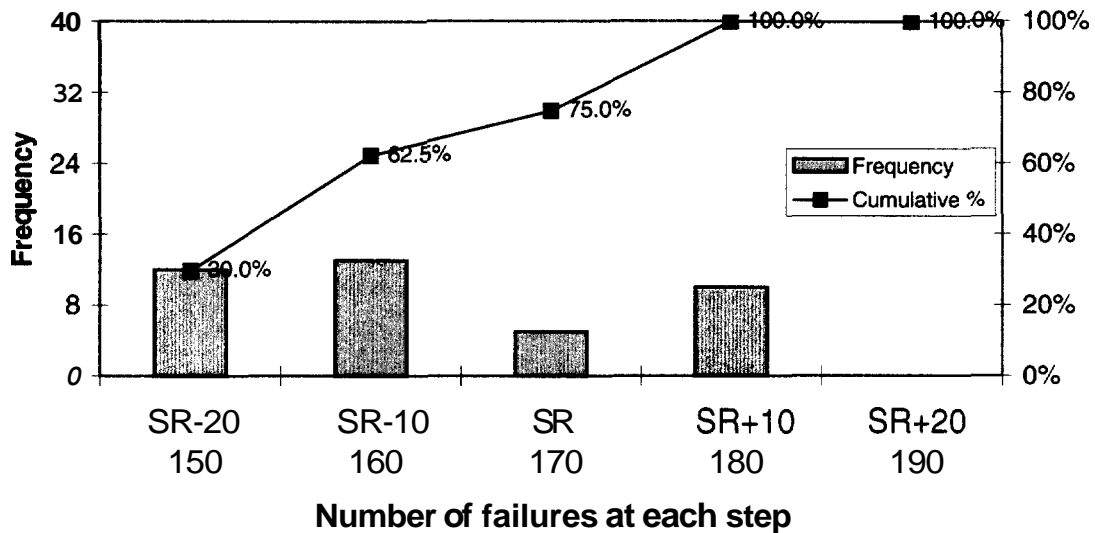
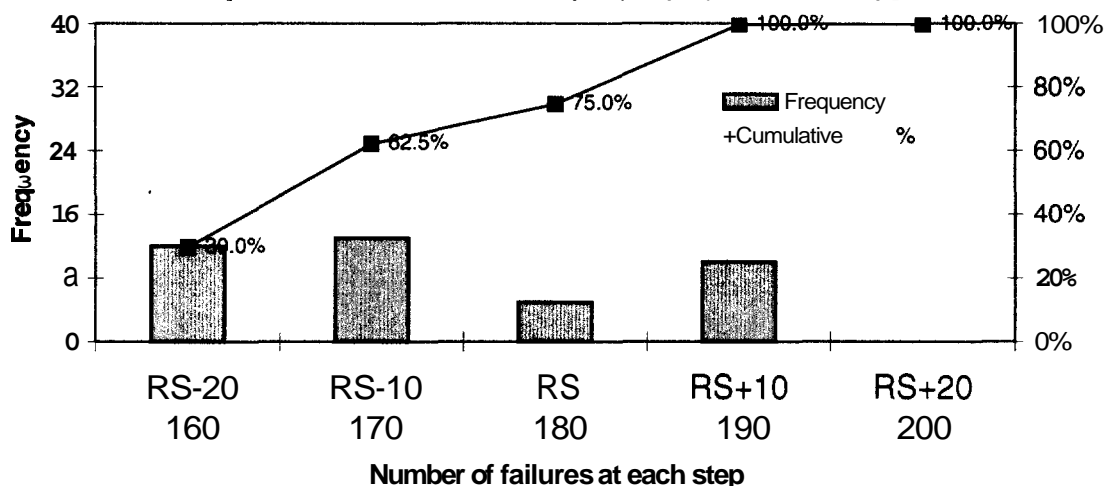


Figure A.3.11 illustrates the distribution of speed-at-failure for S rated tires at 20 psi inflation pressure. The figure shows that about 30 percent of the S rated tires fail to complete the proposed speed criteria of 160km/h.

Figure A.3.11: Estimated distribution of failures with respect to Rated speed for 'S' tires (RS = 180km/h) [70% sidewall load, 140 kpa (20 psi), 20 min step]



As seen in table A.3.3, 75 percent of Q tires fail to complete the test, while 62.5 percent of R rated tires and about 30 percent of S rated tires fail to complete the speed step of 160km/h at 20 psi pressure.

Inflation Pressure	Speed Rating		
	'Q' (160 km/h)	'R' (170 km/h)	'S' (180 km/h)
140 kPa	75	62	30

#### Failure rates for test at 210 & 220 kPa (NHTSA data)

A similar process was followed for tests at 210 and 220 kPa using the NHTSA test data

Figure A.3.12 is a combination of Figures 25, 28, and 31 and shows the estimated distribution of speed-at-failure for 'S' rated tires at 210 and 220 kPa inflation pressure. The figure shows that about 56.7 percent of the 'S' tires fail to complete the 180 km/h ('S' tire speed rating) step of the test.

**Figure A.3.12: Estimated number of failures at each speed step for a 'S' tire data NHTSA**  
[80 & 85% SW load, 210 & 220 kPa pressure, steps 20 min]

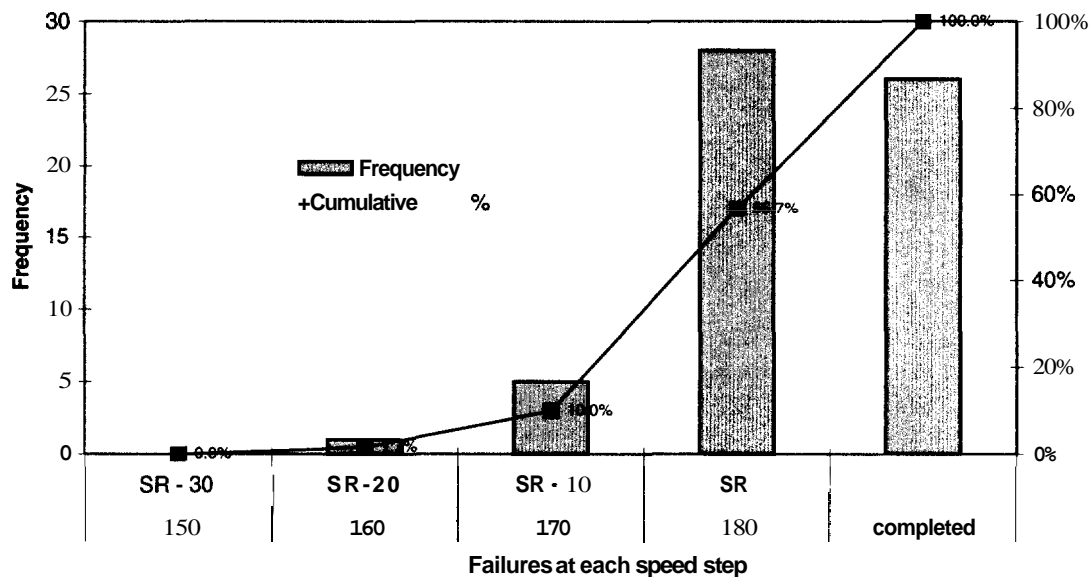


Figure A.3.13 shows the estimated distribution of speed-at-failure for 'R' rated tires at 210 and 220 kPa inflation pressure. The figure shows that about 57 percent of the 'Q' rated tires fail to complete the proposed speed criteria of 160 km/h.

Figure A.3.13: Estimated number of failures at each speed step for 'Q' tires  
[80 & 85% SW load, 210 & 220 kPa pressure, steps 20 min]

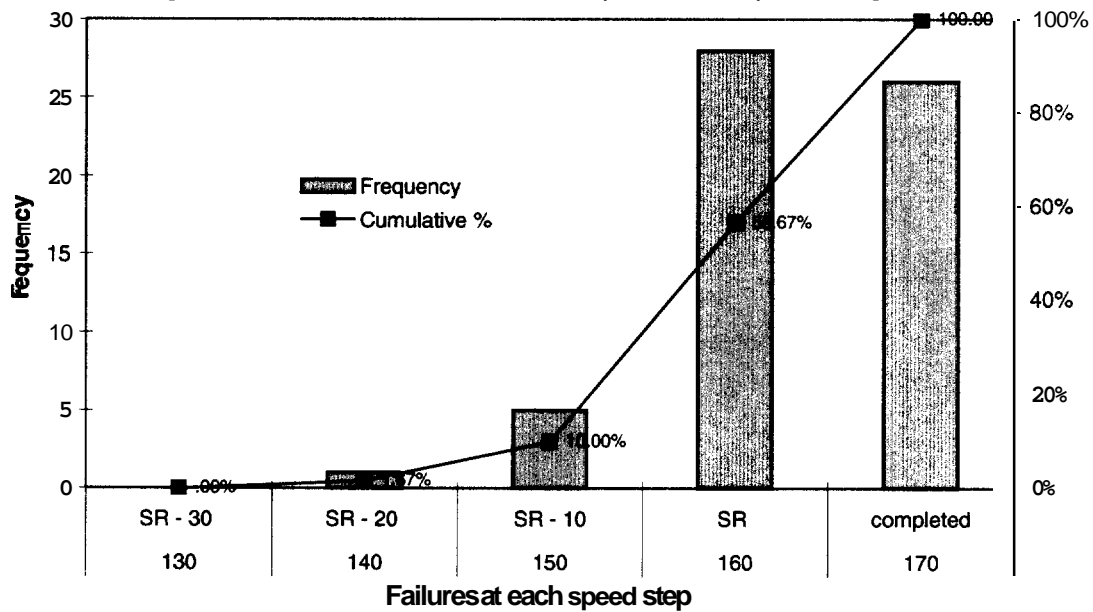
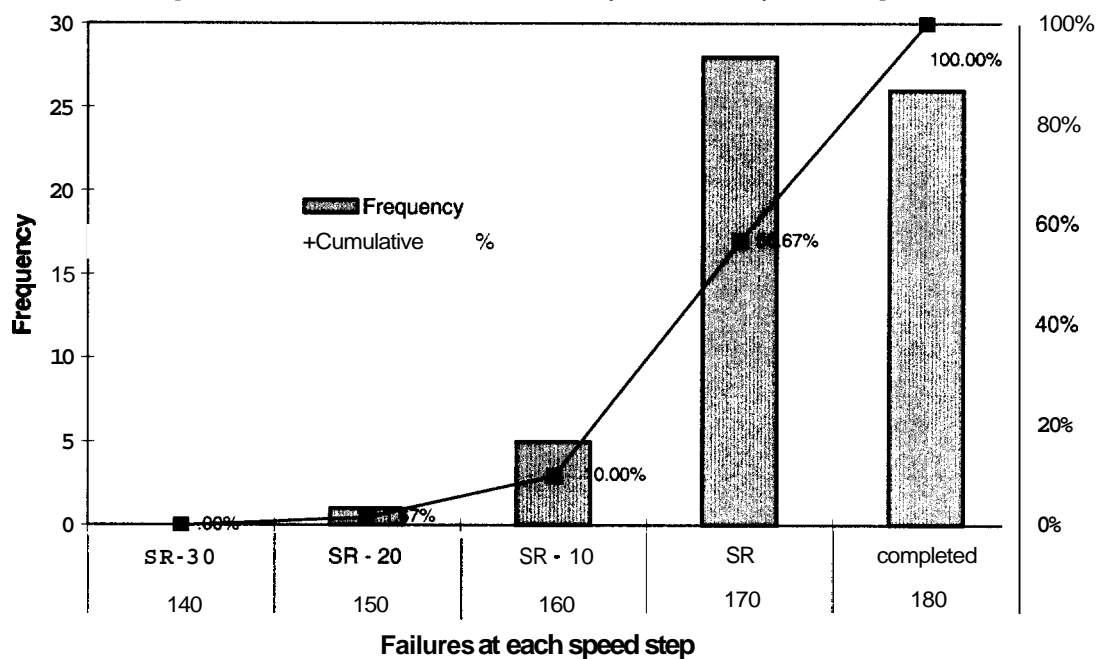


Figure A.3.14 illustrates the distribution of speed-at-failure for 'R' rated tires at 210 and 220 kPa inflation pressure. The figure shows that about 10 percent of the 'R' rated tires fail to complete the proposed speed criteria of 160km/h.

Figure A.3.14: Estimated number of failures at each speed step for 'R' tires  
[80 & 85% SW load, 210 & 220 kPa pressure, steps 20 min]





As seen in table **A.3.3**, **75** percent of **Q** tires fail to complete the test, while 62.5 percent of **R** rated tires and about **30** percent of **S** rated tires fail to complete the speed step of 160km/h at 20 psi pressure.

Inflation Pressure	Speed Rating		
	'Q' (160 km/h)	'R' (170 km/h)	'S' (180 km/h)
210 and 220 kPa	57	10	2